BEGINNING TO FLY

The Book of Model Airplanes

By Merrill Hamburg

Secretary of the Airplane Model League of America

> **'This book will be not only a service to every model-builder, but a worth-while spur to the development of aviation in this country.'**
> ***— Commander Byrd.***

With an Introduction by Richard E. Byrd

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BEGINNING TO FLY

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By Merrill Hamburg

IMAGINE the fun of building a tiny plane with a twelve-inch wing-spread that will leave the floor under its own power, circle gracefully around the room for more than a minute, and swoop to a perfect three-point landing on its own landing-gear. 'Beginning to Fly' will tell you just how to make such a plane in such a clear and detailed manner that you can't possibly fail. And this is only one of the many types described in this book by the Secretary of the Airplane Model League of America.

Commander Byrd has written an Introduction, and the book is endorsed by airplane manufacturers, war pilots, and commercial fliers, who know from experience that making and operating model planes is the best possible way to learn the fundamental principles of flying.

In addition to telling just how to build the planes, the book contains all kinds of interesting facts about aeronautics and gives just the information necessary for obtaining a Boy Scout's Aviation Merit Badge.

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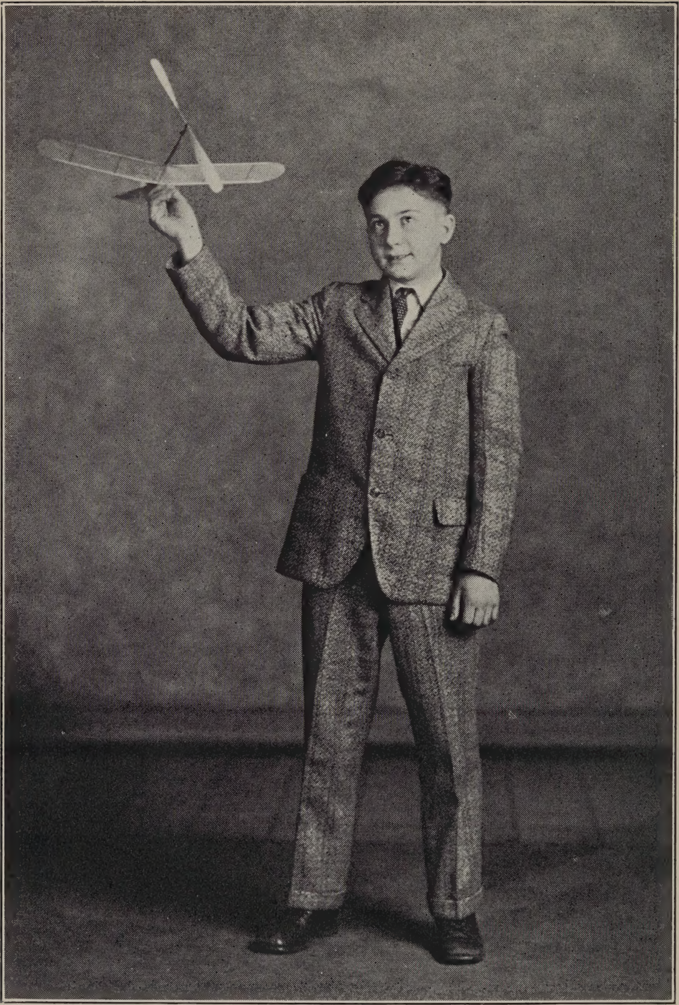

ARAM ABGARIAN SHOWING THE PROPER METHOD OF LAUNCHING AN INDOOR ENDURANCE MODEL

Abgarian established a new world's record of 207 seconds with this model

BEGINNING TO FLY

The Book of Model Airplanes

BY

MERRILL HAMBURG

WITH AN INTRODUCTION BY
COMMANDER RICHARD E. BYRD

With Illustrations and Diagrams

BOSTON AND NEW YORK
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TO

WILLIAM B. STOUT

IN APPRECIATION

OF HIS ACTIVE INTEREST

IN THE PROMOTION OF

MODEL AVIATION

PREFACE

THE rise in popularity of model airplane construction, during the past two years, has been tremendous. There probably isn't a town or village in the United States where at least one parlor hasn't taken on the semblance of an airport. Thousands of schools are adopting model aviation in their manual training departments, either as a regular or spare-time study. More than thousands of basements are being converted into airplane factories.

The reason for this popularity isn't hard to find. Many leaders in aviation testify that they got their start by building and flying models. There's a fascination in the little ships that fly so smoothly and gracefully. And their construction is within the power of any boy or girl who has moderate skill in handling a few simple tools.

Mr. Merrill Hamburg's many years of experience in teaching model aviation in Detroit public schools, and his wide contacts as secretary and technical adviser of the Airplane Model League of America, qualify him eminently for the authorship of this book. Many of you already know him as the writer of the series of airplane model articles that have appeared in *The American Boy.*

The book fills a long-felt want in the library of the air. In it, you will be introduced to the types of models that have set world's records. As you build them, you will be following in the footsteps of Glenn Curtiss, William B. Stout, John Carisi, and other great designers of modern aircraft who began their careers by constructing and flying models.

Griffith Ogden Ellis
Editor of The American Boy
Vice-President of the Airplane Model League of America

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AN INTRODUCTION

By Commander Richard E. Byrd

Few activities will so certainly guarantee the progress of aviation in the United States as the building of airplane models. The model aviators of to-day will be the regular patrons of the airways of to-morrow. From their ranks will come the designers of the new ships of the sky that will supersede present aircraft.

I have watched with intense interest the great growth of the Airplane Model League of America, which is represented by thousands of members in every State of the land. I am glad that Mr. Hamburg, its secretary, is giving builders the results of his years of experience, and I know that his book will be not only a service to every model-builder, but a worth-while spur to the development of aviation in this country.

R E Byrd

BEGINNING TO FLY

CHAPTER I

HISTORY OF AERONAUTICS

FROM prehistoric time all down through the ages man has looked upon the flying bird with envy. The earliest legends were filled with impossible accounts of man flying through the air, and as time passed these stories grew, often giving the details of the supposed flights. Whether these legends are pure myths, the results of the imaginations of the early bards, well rounded out from telling and retelling, or whether they had their beginnings in man's early experiments in trying to take to the air, cannot be determined. However, there is much in many of these stories that comes under the range of possibility.

Such is the story of Dædalus and Icarus. We can easily conceive of Dædalus, after watching the ease with which birds were able to fly, deciding he too could fly by fashioning a pair of wings. What would be more natural than that Icarus, knowing his father's plans, should desire to be first to fly, and that, securing the wings, he should proceed to a near-by cliff for the take-off. Jumping from the precipice, he falls to his death on the rocky shore of the sea that to this day bears his name. The legend as we know it to-day could easily have been woven about such a simple happening.

Other stories, whether pure myths or based on facts, bear out the desire of man to fly. There is the rather humorous account of Simon the Magician being prayed down to his death by the Apostle of the Lord. One version has it that it was Saint Peter, and the other, Saint Paul, that did the praying, but both versions agree that it was Simon's neck that was broken when he fell into the Roman Forum, having been stopped midway in a successful flight by the heavenly intervention at the behest of the Saint. Again there is the incident of the Saracen of Constantinople, who, by the aid of a long robe stiffened by rods, hoped to be able to fly around the Hippodrome. It is said that he jumped from a tower and at first rose into the wind like a bird, but, losing his momentum, fell to his death. Such are stories, half legend and half history, that are handed down to us of man's early desire to fly.

The first scientific investigator whose work stands today was Leonardo da Vinci. He not only stated some of the basic principles of artificial flight, but found time to make many drawings and sketches which bear a surprising resemblance to some of the first successful aeroplanes. He is credited also with the invention of the helicopter and the parachute and is said to have made successful models of both of these. This is indeed remarkable when we realize that, although da Vinci's chief fame rests on his ability as an artist, he was also famous in his day as an architect, engineer, and scientist, making many contributions to each of these fields.

It remained for Francesco Lana in the seventeenth century to propose the first lighter-than-air craft. His plan, although impossible, is highly interesting, as it shows a surprising degree of scientific thought and research. By exhausting the air from globes constructed of thin copper he hoped to obtain a buoyant force sufficient to lift a ship containing men. This ship was to be propelled by sails and oars. Of course his whole theory was impracticable, because of the fact that such a globe will collapse when the air is exhausted from it.

The first successful balloon was constructed by the Montgolfier brothers, who became interested in the subject upon observing that a skirt hung on a line over a fire to dry, would, when filled with hot air, rise until it overturned and allowed the air to escape. They experimented with paper bags which they developed into small balloons and finally decided to build a large one.

On June 5, 1783, a large crowd assembled at Versailles to see the first balloon flight. This first hot-air balloon traveled several miles, and on landing was completely destroyed by the peasants, who thought it was a monster from the upper regions. Not long after this the brothers sent up another balloon carrying live passengers, a sheep, a rooster, and a duck making up the aërial passenger list. This flight was made to determine whether life could exist in the rarefied air above the earth. Although the flight was successful, the question arose as to the possibility of man not being able to live, even though the animals did. It was finally determined to test this by strapping two condemned criminals to a balloon. They reasoned that, as the men were condemned to death, nothing would be lost if they were killed. However, they did give the men a faint ray of hope by promising them their freedom in case of a successful flight. But, when everything was ready, one Pilâtre de Rozier protested against allowing the honor of the first flight by man to go to criminals, and announced his willingness to undertake the trip. Over his protests he was prevailed upon by his friends to make the first attempt in a balloon held down by ropes. In November, 1783, he made the first flight in a free balloon that history records. Later in the same year the Montgolfier brothers furnished the bag and a French chemist, named Charles, supplied the hydrogen for the first hydrogen balloon. These flights definitely divided aeronautics into two distinct fields, namely, lighter-than-air craft and heavier-than-air craft.

Following this period there were many theories advanced and experiments made in aviation; while some were practicable, others were very impracticable. In 1840 George Pocock, of Bristol, invented the first man-carrying kite and successfully demonstrated it, raising a passenger as high as a hundred yards from the ground. He was closely followed by Henson and John Stringfellow, who built the first steam-driven monoplane. This first ship, although a failure, encouraged Stringfellow to continue experimenting, and in 1848 he built and successfully flew a similar type of ship, but of smaller design.

After Stringfellow gave up his work there was a long period in which very little was accomplished in the science of aviation. Toward the latter part of the nineteenth century there was considerable work done with gliders. The most important was done by Lilienthal in Germany, by Le Bres in France, by Pilcher in England, and by Chanute, Montgomery, and the Wrights in America. Space does not permit us to go into detail regarding the work of each of these, but in passing we should point out that the knowledge gained from these experiments with gliders made the power-driven aeroplane possible.

Dr. Samuel P. Langley began a series of experiments about 1891 with rubber-driven models which demonstrated the practicability of heavier-than-air machines. Later he made some very successful steam-driven models that flew almost a mile. The success of these models determined Langley to build a man-carrying machine.

In October, 1903, all was ready for the test, the engine started, and everything working fine, when on leaving the track the plane was caught and dumped ingloriously into the water. It was given a second test on December 8, 1903, only to have a similar accident, almost completely wrecking it and causing it again to drop into the river. In both of these flights the method of launching was from a track built on the roof of a house boat.

Just nine days later, December 17, 1903, the Wright brothers made their first power-driven flight and the conquest of the air was completed. It is interesting to note that the story is told that these brothers, while mere boys, were interested in the study of aeronautics, upon being presented with a small toy helicopter by their father. The first flight was the result of years of study and numerous experiments with gliders. When they had secured sufficient information to warrant a trial flight, they began looking around for a power plant. As there was not an engine available, suitable for their purpose, they decided to build one. It is said that a certain engine manufacturer refused to accept the job, as he would not have his men waste their time building an engine for such useless experiments. In their first trials the brothers, between them, made four successful flights, the first of only twelve seconds and the last and longest of fifty-nine.

The machine was taken back at the end of these tests to their camp and left supposedly in safety. A sudden gust of wind caught and overturned the plane before any one could reach it, so completely wrecking it that it was useless for further experiments.

By continuing their investigations and improving their machine, the Wright brothers were able, by July, 1909, to pass the tests for a successful aeroplane as prescribed by the United States Government. To pass these tests the ship had to be capable of carrying two men with a flying range of one hundred and twenty-five miles at forty miles an hour.

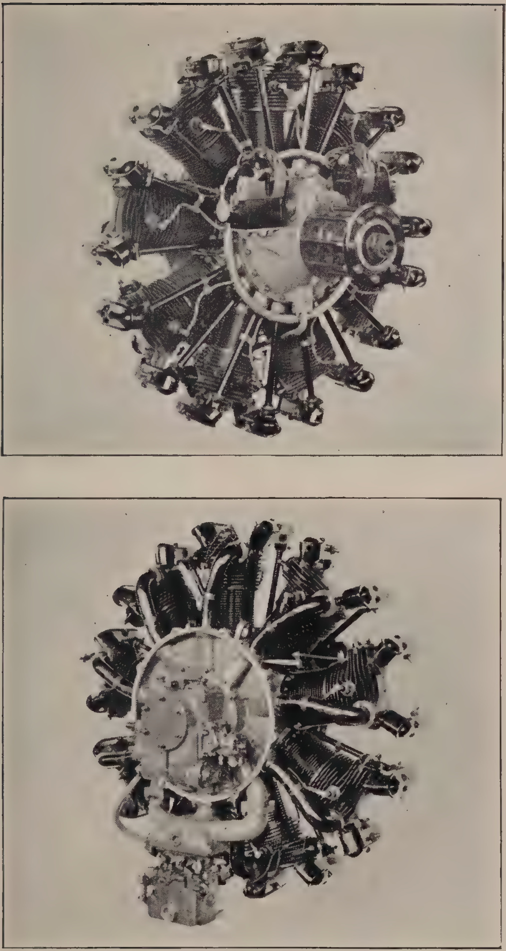
It seems almost impossible that the present aeroplane could be developed from the original Wright plane in the twenty-five years since the first flight.

Immediately following the feat of the Wright brothers, interest in aviation became very marked, especially in Europe. During the years of 1903–11 there were numerous experiments and investigations carried on by such men as Louis Blériot, Maurice Farman, Hubert Lathan, Alberto Santos-Dumont, the latter being the next to accomplish power-driven flight. In America, Glenn Curtiss, Dr. Alexander Bell, and two associates organized the Aërial Experiment Company. S. F. Cody was another pioneer in aviation that should be mentioned; an American by birth, but a British subject, he was the first to fly in England. His unusual ability as a flier and his great daring attracted attention throughout Great Britain. Just to mention all the famous flights and fliers of this time would fill volumes, and in order to get as much as possible into one chapter the most noteworthy of these events will be given in a short summary in the order in which they took place.

Undoubtedly the World War gave a greater impetus to the advancement of aviation than any other event before or since. Up to this time the airplane's value as a weapon had not been fully realized and very little had been done directly by any government to materially advance its development. Very early in the war, however, it became evident that the side which held the balance of power in the air would have a distinct advantage. As soon as this was realized the race for supremacy was on, and the warring factions put their best brains to developing the airplane and its accessories. The most outstanding achievements of this period were: the development of aërial photography; the successful designing of large ships for bombing; a system of gearing the timing mechanism to machine guns, called synchronization; permitting the guns to be fired between the revolving blades of the propeller without injury to them; the advancement made in building inherent stability into the planes; the great improvement in the design of airplane engines both from the standpoint of power and reliability; and last but not least the great strides that were made in the art of flying by individual pilots. This last was due largely to the necessity for a pilot to be able to get the maximum from a ship under all conditions. Rookie flyers were taught to do stunts that before the war were seldom tried by the oldest veterans.

Since the war aviation has advanced steadily, especially in the commercial field. As evidence of this we have in America the highly developed air mail system, a number of passenger-carrying transport lines, and an increasing number of firms and individuals using the air for rapid transportation of parcel goods. Europe has its large and ever-increasing number of passenger lines, meeting their schedules day after day in all kinds of weather in a way that rivals the railways and with the added element of speed with its saving of time.

The most discussed events that have taken place in aviation since the war have been the numerous long flights. For the most part these have been very successful, especially where proper preparations were made beforehand, and have proved the reliability of the airplane far beyond the dreams of the early pioneers. It is the opinion of many of the leaders in aviation, however, that long and dangerous flights should be discouraged, as they bring more adverse criticism of the industry when unsuccessful than favorable comment when they are successful. These long-distance flights began shortly after the close



TWO VIEWS OF WRIGHT WHIRLWIND J-5 NINE-CYLINDER AIR-COOLED RADIAL ENGINE, RATED H.P. OF 210 AT 1800 R.P.M.

of the war with the successful crossing of the Atlantic by Commander Read, of the United States Navy, in the flying boat NC–4 during May, 1919; they reached the peak in 1927 with the numerous attempts at non-stop flights.

A history of aeronautics would not be complete without at least a short account of the development of aerostatics, lighter-than-air craft. As stated at the beginning of the chapter, Lana was the first to propose a definite design for this type of ship, while to the Montgolfier brothers goes the credit of constructing the first successful balloon. This definitely divided the field of aeronautics into two distinct groups; that is, aviation, the art of operating heavier-than-air craft, and aerostation, the art of operating lighter-than-air craft.

Shortly after the discovery of hydrogen by Cavendish in the year 1776, experiments were made with the new gas for filling small balloons. The first large balloon to use hydrogen was constructed by the noted aeronaut Charles. By treating a half-ton of iron filings with a quarter-ton of sulphuric acid, he generated enough hydrogen in four days to make a very rapid ascent, using a rubberized silk bag. As this balloon was not provided with any means by which the gas could escape, it probably burst on reaching a high altitude.

During the latter part of the eighteenth century ballooning became very popular. Clubs were organized and many contests held. It was during this period that Blanchard succeeded in crossing the English Channel in a balloon. Rozier, the first man to pilot a free balloon, was killed trying to duplicate the feat with one, so constructed that hydrogen was contained in the top section and hot air in the lower. The explosion occurred high in the air, when hydrogen, leaking into the lower section, was ignited by the heating device. Thus the first man to make a balloon flight also became the first victim of aeronautics.

A French general called Meusnier was the first to propose a dirigible, a balloon that could be driven and steered in any direction the operator wished. His plan called for a rigid connection between the control car and the bag, both to be elliptical in shape, to cut down resistance, and for three propellers driven by hand, requiring a crew of eighty men. The balloon was never constructed, but many of his ideas were used and proved practical in later ships. Giffard, an inventor, using the elliptical bag with a steam engine for power was the first to build and fly such a ship. There were a number of similar experiments, more or less successful, made with dirigibles about this time. The two most successful designers, Zeppelin in Germany and Santos-Dumont in France, began their work toward the end of the nineteenth century.

Dumont, a Brazilian, had constructed fourteen dirigibles in all before he gave up building lighter-than-air craft to work on airplanes, on learning of the success obtained by the Wright brothers. A very interesting account of his experiments is given in his book, 'My Airships.' His first ship, a small one, powered with a three horse-power motor, made only one successful flight. He built ship after ship with various improvements, and demonstrated their reliability by a great many flights. It is told that he amazed and delighted the Parisians by flying from his country home to his city residence for breakfast and, after the completion of the meal, back again. He even went so far as to design types, much as the automobile manufacturers do to-day. At one time he had as many as three, an omnibus, a racing ship, and a town runabout. All these ships were of the non-rigid type.

Ferdinand von Zeppelin, a retired German army officer, began work on his first airship in 1898. This ship, the first rigid dirigible ever built, was constructed with an aluminum framework covered with fabric. Two control cars were rigidly attached to the framework, each containing a sixteen horse-power motor used in driving the propellers. This ship was able to make over twenty-one miles an hour. Zeppelin set out immediately to construct a second ship, which was followed by the construction of numbers three and four. All of these ships were given the name of Zeppelins and proved so reliable that when number four was destroyed in a storm, enough money to continue the work was quickly raised by popular subscription. A company was organized to direct the expenditure of this money which immediately began operation by securing an experimental field and by the construction of a factory. The Zeppelin Company soon began establishing landing-fields and started a regular passenger service. The improved Zeppelin provided many comforts that were unthought of up to that time in any type of aircraft. At the outbreak of the World War, Germany had thirty of these ships for military purposes. Most of the airships that have been built since the beginning of the war are more or less in imitation of the Zeppelins. The most outstanding flights made by these will be found in the following summary in the order that they were made.

AVIATION

SUMMARY OF IMPORTANT EVENTS

December 19, 1903

Orville Wright made the first flight in power-driven airplane. The plane, called the Kitty Hawk, flew 852 feet.

September 26, 1905

Wrights made the first officially recorded flight at Dayton, Ohio. Distance 11.12 miles. Time 18 minutes, 9 seconds.

September 14, 1906

Alberto Santos-Dumont succeeded in making a flight of eight seconds. He was first to succeed after the Wright brothers.

April 5, 1907

Louis Blériot made a flight of six seconds.

October 15, 1907

Henry Farman made his first flight of 935 feet, using a Voisin biplane.

October 25, 1907

Farman made first turn in the air.

March 29, 1908

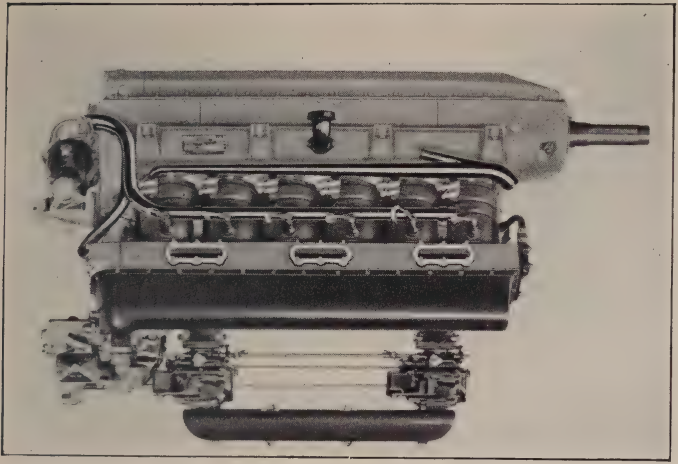
Farman, carrying Léon Delagrange, made the first recorded flight with passenger.

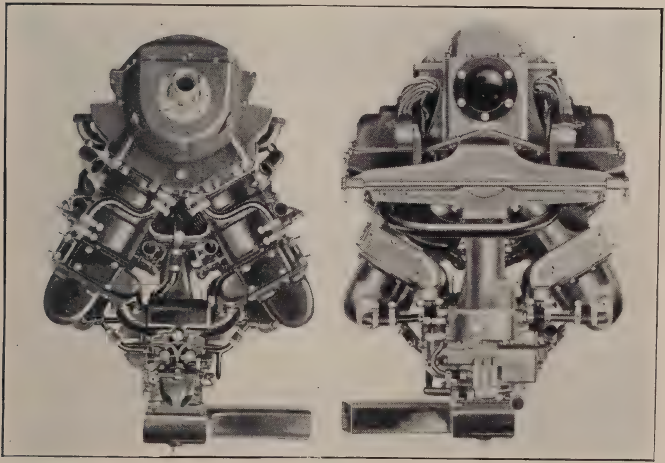
July 8, 1908

Léon Delagrange made the first flight with a woman, Madame Peltier, as passenger.

September 12, 1908

Orville Wright crashed his machine at Fort Meyer, Virginia, resulting in the first airplane fatality. Wright was severely injured and his passenger, Lieutenant Selfridge, was killed.





PACKARD MODEL 2A-1500 INVERTED AIRCRAFT ENGINE
Bore 5⅜ in.; stroke 5½ in.; displacement 1530 cubic in.; rating 600 B.H.P. at 2500 R.P.M.

July 25, 1909

Louis Blériot made first airplane flight across the English Channel.

August 22, 1907

Opening day of the first airplane meet. The meet was held at Rheims, lasting one week, with thirty entrants contesting.

August 28, 1909

Glenn Curtiss at the Rheims meet won the first Gordon-Bennett cup.

September 17, 1911, to November 5, 1911

First transcontinental airplane flight in America, a distance of 3390 miles by C. P. Rogers. Flight started in New York and ended in Pasadena.

May 28, 1914

Glenn Curtiss flew the reconditioned but original Langley plane for a distance of 150 feet at Lake Keuka. About the only change was the addition of floats.

1914 to 1918

Period of World War. So many events happened during this time that it would be impossible to attempt to give them in so limited a space. Only a few of the most famous aviators of the war are given.

American aviators

Captain E. V. Rickenbacker — 26 victories. Squadron Commander 94th Pursuit (Hat-in-the-Ring Squadron).

Frank Luke — 18 victories in two months.

Major Raoul Lufbery — 17 victories officially credited to him; the actual number was over twice this many, but not confirmed.

British aviators

Captain Albert Ball — 44 planes.

Colonel William Bishop — 72 planes — known as 'Ace of Aces.'

French aviators

Captain George Guynemer — 53 victories.

Captain René Fonck — 75 victories.

Captain Charles Nungesser — 36 victories.

German aviators

Captain Freiherr von Richtofen — 80 victories, Commander Famous Flying Circus.

May 8 to May 31, 1919

Lieutenant Commander Read made first trans-Atlantic flight from Rockaway, by way of Newfoundland, The Azores, Lisbon, and then to Plymouth, England, where the flight ended. The ship used was the NC–4 seaplane equipped with four Liberty motors each developing 350 horse-power.

June 14, 1919

Captain Alcock and Lieutenant Brown, Englishmen, made the first direct crossing of the Atlantic from Newfoundland to Ireland, a distance of 1880 miles. Time approximately 16 hours.

October 8 to October 16, 1919

Lieutenant B. W. Maynard flew from the Atlantic to the Pacific and return. Time 9 days, 4 hours, 26 minutes.

November 12 to December 10, 1919

First flight from England to Australia. Pilots Sir Ross Smith and his brother Sir Keith Smith. Distance 11,060 miles.

July 15, 1920

U.S. Army Alaskan flight, New York to Nome and back to New York. Distance over 7000 miles. Trip successfully completed by all four planes.

May 2 and 3, 1923

Non-stop transcontinental flight by T–2 from Mitchel Field, New York, to Rockwell Field, San Diego. Pilots Lieutenants Macready and Kelly. Time 26 hours, 50 minutes. Distance 2550 miles.

June 1, 1923

Lieutenant Maughan made first dawn to dusk flight from New York to San Francisco. Total distance 2670 miles. Time 21 hours, 48 minutes.

August 27, 1923

First refueling in the air from one airplane to another. Pilots Captain L. H. Smith and Lieutenant J. P. Richter.

April 6 to September 28, 1924

First round the world flight by four United States Army Air Service planes. Distance 28,000 miles. Time 5 months, 24 days. Actual time in air 371 hours, 11 minutes. Planes, Douglas biplanes.

January 29, 1926

Lieutenant John A. Macready established and set new altitude record at McCook Field, Dayton, Ohio, reaching a height of 38,704 feet.

May 9, 1926

Commander Byrd and Floyd Bennett flew from Spitzbergen to North Pole and return. Time 15 hours.

April 12 to 14, 1927

Clarence Chamberlin and Bert Acosta established American endurance record of 51 hours, 12 minutes.

May 21–22, 1927

Colonel Charles A. Lindbergh made first New York to Paris flight. Distance 3600 miles. Time 33 hours, 29 minutes, 30 seconds. Ryan monoplane equipped with Wright Whirlwind Motor.

June 4–5, 1927

Clarence Chamberlin, with Charles Levine as passenger, flew from New York to Helfta, Germany. Distance 3905 miles. Time 42 hours, 45 minutes, 30 seconds.

June 28, 1927

Lieutenants Lester J. Maitland and Albert Hegenberger, in a Fokker three-motored (Wright Whirlwinds) army transport, flew from Oakland, California, to the Island of Oahu, Hawaii. Time 25 hours and 50 minutes.

June 29, 1927

Commander Richard Byrd, Lieutenant Bertram Acosta, Lieutenant George Neville, and Lieutenant Bernt Balchen flew the three-motored Fokker America to France from the United States. Out of gas and lost in fog, a forced landing was made at Ver-sur-Mer, a small town 125 miles from Paris. Distance 4200 miles, time 40 hours.

August 17, 1927

Arthur C. Goebel won first place in Dale flight from Oakland, California, to Hawaii. Time 26 hours, 17 minutes, 33 seconds, Woolaroc Monoplane.

December 14, 1927, to February 13, 1928

Colonel Charles A. Lindbergh made Pan-America Good-Will trip. Non-stop flight from Washington, D.C., to Mexico City. Visited fifteen nations and dependencies in a circuitous route through Central and South America and the West Indies. Trip finished in non-stop flight from Cuba to St. Louis. Total distance of tour 9000 miles.

Aerostatics

SUMMARY OF IMPORTANT EVENTS

1776

Cavendish discovered hydrogen.

June 5, 1783

Montgolfier brothers made first public exhibition.

August 29, 1783

A chemist named Charles made the first successful hydrogen-filled balloon exhibition.

September 19, 1783

Montgolfier brothers sent up first balloon carrying live passengers; a sheep, a duck, and a cock.

October 15, 1783

Pilâtre de Rozier made the first balloon ascension.

November 21, 1783

Pilâtre de Rozier and the Marquis d'Arlandes made the first ascension in a free balloon.

December 28, 1783

James Wilcox of Philadelphia made the first free balloon ascension in America.

July 16, 1785

Pilâtre de Rozier with a companion was killed when their hydrogen balloon exploded while in the air in an attempt to cross the English Channel.

January 17, 1785

Jean-Pierre Blanchard and Dr. Jeffries, an American, made the first crossing of the English Channel in a free balloon.

1852

Giffard built and successfully operated the first power-driven balloon.

September 20, 1898

Santos made his first successful flight in his non-rigid type of dirigible.

July, 1900

Ferdinand von Zeppelin made his first flight in his rigid type airship.

November, 1917

The German airship L–59 made its memorial non-stop flight to relieve German troops in East Africa. Load carried fifty tons. Distance covered 4225 miles.

July 2–13, 1919

Major G. H. Scott flew across the Atlantic from England to New York in the R–34 with a crew of thirty. The trip from England to New York took 108 hours, 12 minutes. The return trip was made in 75 hours, 3 minutes.

October 12–15, 1924

Flight of the ZR–3 (Los Angeles) across the Atlantic Ocean to Lakehurst. Distance 5066 miles. Time 81 hours, 17 minutes.

May 11, 1926

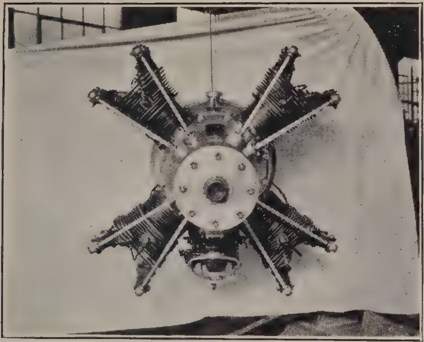
Italian airship Norge, with Amundsen, Ellsworth, and Nobile, left Spitzbergen for the flight across the North Pole to Nome, Alaska.

CHAPTER II

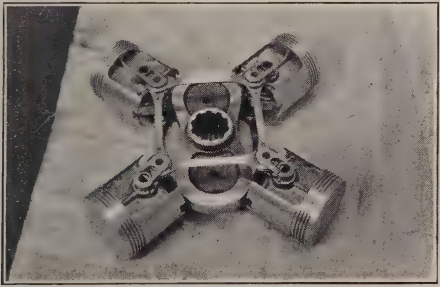
AIRCRAFT AND POWER PLANTS

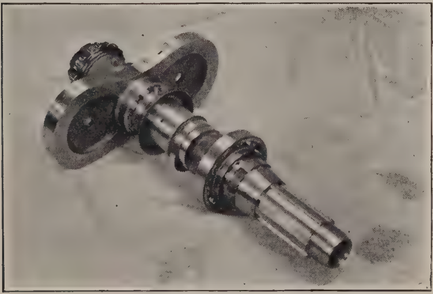
THE science of aeronautics is divided into two general classes, according to the method depended on to obtain the lift or buoyant force necessary to sustain the craft while in the air. The first class is known as aviation, the art of operating heavier-than-air craft which receive their lift from aerodynamic forces. The second is known as aerostation, the art of operating lighter-than-air craft. These are sustained in the air by the buoyant force of gases. Heavier-than-air craft can remain in the air only when in motion, while lighter-than-air craft can remain stationary in the air when the lifting or aerostatic forces are equal to the weight of the entire craft including equipment and crew, or while anchored.

The spherical or free balloon, the non-rigid and the rigid airship, are the best examples of lighter-than-air craft. The pilot of the free balloon is more or less at the mercy of the winds; although he may select or find a favorable wind he never is sure how long it will last. Because of this the balloon is used mainly for scientific investigations and by sportsmen. Realizing the necessity of being able to guide the flight of a balloon, the earliest pilots began experimenting with methods by which they could gain directional control. The dirigible or steerable balloon has been evolved from these experiments. These



ASSEMBLED FAIRCHILD CAMINEZ ENGINE





ASSEMBLED CRANK SHAFT, SHOWING CAM AND METHOD OF USING CAMS INSTEAD OF THE USUAL CONNECTING-RODS

in turn are divided into the non-rigid, semi-rigid, and the rigid airships.

Non-rigid dirigibles are usually composed of an elongated bag, supporting, by means of ropes or cables, a control car, equipped with engines and propellers.

The semi-rigid differs from the non-rigid airship in that it has a rigid frame or keel running from the nose to the stern. This stiffens the entire bag, helping it to retain its shape as well as distributing evenly throughout the bag the weight of the gondolas, or control cars. The Italians are the foremost advocates of this type of ship.

The rigid airship has a rigid framework covered with fabric and contains gas bags or cells. Control cars are attached by means of solid supports to the framework. Count von Zeppelin built the first rigid airship and without doubt has contributed more to the success of this type of aircraft than any other person.

The following types of aircraft are classed under the heading of aviation: the kite, the parachute, the glider, the ornithopter, the helicopter, and the airplane. The first two are familiar and need no introduction. The glider is a form of airplane without a power plant, and like the airplane it cannot remain in the air unless in motion relatively to the air. Gliding flights are as a rule started from the top of a hill, allowing the machine a chance to gain speed by losing altitude. By taking advantage of the shifting air currents, experienced pilots have been able to keep their gliders in the air for hours at a time. Aircraft designed to fly by flapping wings, similar to the flight of birds, are called ornithopters. Although the earliest experiments by men in aviation were with this type of machine, so far, because of structural difficulties, none of these have been successful. It has been often pointed out that one of the chief reasons why the airplane has not been more popular is due to the fact that one must have the use of a large landing-field wherever one flies. Many attempts have been made to develop a ship that would rise vertically. This would, of course, do away with the necessity of a large airport. Although as yet of no commercial value, a number of these experiments have been successful. The lift for most of these is derived from rotating airfoils or wings similar to propellers. Such a ship is called a helicopter. The airplane, familiar to every one, is the most important of the heavier-than-air craft. It may be defined as a mechanically driven heavier-than-air craft, fitted with fixed wings and supported by the action of the air on these.

When an airplane has but one wing, it is known as a monoplane; when it is equipped with two wings, it is called a biplane; likewise when with three wings, a triplane, and when with more than three, a multiplane. If the propellers are placed in front of the wings, the airplane is called a tractor; when the propellers are placed behind the wings, it is said to be a pusher. When the airplane is equipped as both a pusher and tractor, it is said to be a combination. Airplanes are also spoken of as single-engine and multi-engine, depending on whether they have one or more engines.

Some airplanes are equipped to take off and land on water; these are known as seaplanes. If the plane is equipped with floats, it is said to be a hydroairplane. Some seaplanes are equipped with a hull or boat-like structure that furnishes buoyancy when in contact with the surface of the water. It usually contains accommodations for the crew and passengers and as a rule serves as both float and fuselage. This type of seaplane is called a flying boat. An airplane equipped with both floats and wheels and designed to rise from, and alight on, either land or water, is called an amphibian.

All internal combustion engines used in airplanes are generally classified according to the method of cooling. These are again classified with reference to arrangement of the cylinders and cam shaft. Both the water-cooled and air-cooled engines have their advantages and disadvantages. The air-cooled engine is generally conceded to have the following advantages over the water-cooled:

a. The air-cooled engine transfers the heat of combustion from the cylinders to the atmosphere. The water-cooled engine transfers this heat to the cooling water and then by means of a radiator to the atmosphere. Because of the elimination of the heavy cooling system the air-cooled motor is much lighter.

b. The air-cooled motor, being much lighter, permits a considerable saving in the weight of the entire airplane construction.

c. The parts of an air-cooled motor are more accessible, cylinders and their accessories are interchangeable, and any one may be removed without interfering with the adjacent cylinders. The air-cooled engine as a rule can be completely overhauled without removing from the plane.

Engines are classified according to the arrangement of their cylinders. The following definitions explain the different types:

Barrel type engine — An engine having its cylinders arranged equidistant from and parallel to the main shaft.

Radial engine — An engine having stationary cylinders arranged radially around a common crank shaft.

Rotary engine — An engine having revolving cylinders arranged radially around a fixed crank shaft.

Inverted engine — An engine having its cylinders below the crank shaft.

Vertical engine — An engine having its cylinders arranged vertically above the crank shaft.

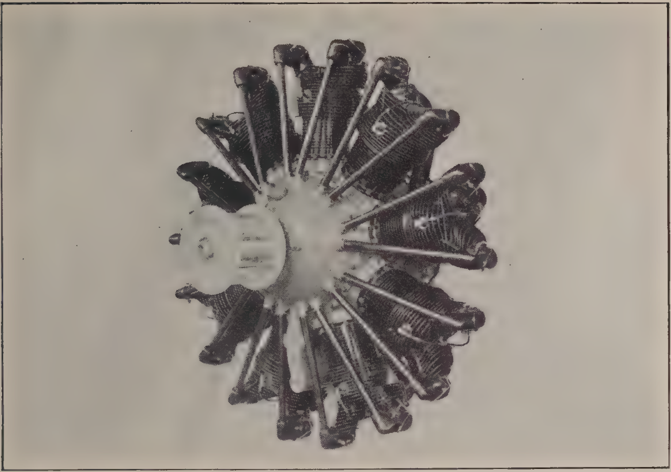
V or Vee engine — An engine having its cylinders arranged in two rows so that an end view of the motor forms a letter 'V.'

W engine — An engine having its cylinders arranged in three rows so that in the end view they form a letter 'W.'

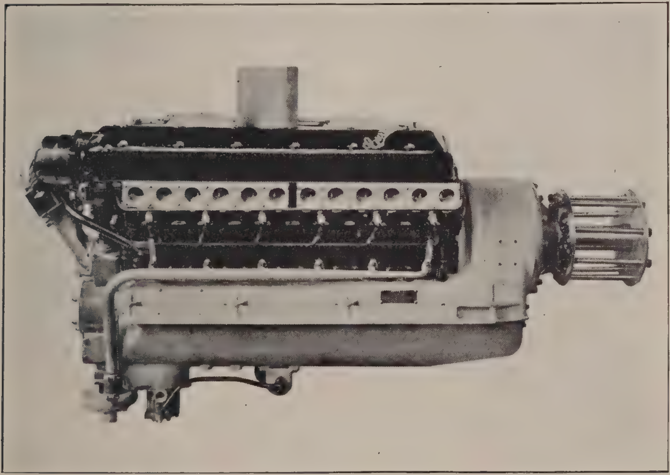
X engine — An engine having four rows of cylinders whose axes meet at the crank shaft center in a manner resembling the letter 'X.'

Flat engine. An engine having cylinders arranged in two rows on opposite sides of the crank shaft.

The selection of engines for any given airplane depends on a number of factors, such as speed, power output, torque curve, balance, cooling, and the convenience of arrangement. A complete discussion of these characteristics for the different types of engines may be found in a number of books on this subject.



PRATT & WHITNEY 400-H.P. 'WASP'



CURTISS GEARED V-1550 WATER-COOLED ENGINE
Develops 575 H.P. at 2500 R.P.M. Displacement 1550 cubic inches

Because of the elimination of the complicated cooling system, which is the source of thirty per cent of the forced landings in airplanes using this type of engine, the air-cooled motor is more reliable. Performance seems to show that the air-cooled motor does not need overhauling as often as the water-cooled engine. It is not uncommon for one to run over three hundred hours without any major adjustments being made.

The air-cooled motor warms up much faster than the water-cooled. The water-cooled motor has its chief advantage in that it lends itself more readily to the design of the entire airplane. With this type of engine the fuselage may be stream-lined and the resistance of the entire plane reduced materially. In the larger air-cooled motors the diameter often offers considerable resistance in addition to blanketing the propeller.

A number of photographs, showing representative engines of the different types, are given. All of these engines have made excellent records in their class and are considered very highly by the aeronautical industry.

CHAPTER III

AIRFOIL SECTIONS

WE are apt to think of air as something that has neither weight nor volume, but this is not so. Air is a mixture of a number of gases, the greater part being nitrogen and oxygen. Under standard conditions, 0° C., and 760 mm. pressure, air weighs 1/773 as much as an equal volume of water.

Archimedes' principle, that the buoyant force exerted upon a body immersed in a fluid is equal to the weight of the fluid displaced, applies to both air and water. The excess buoyancy, therefore, of any object immersed in air is equal to the weight of the air displaced less the weight of the object. If the object is heavier than the weight of air displaced, it will not float.

In order to secure buoyancy in lighter-than-air craft, envelopes are filled with gases, such as hydrogen or helium, which are lighter than air. If the weight of the gas used is known, the amount of lift of an airship may be calculated by subtracting the total weight of the ship, including the gas used, from the weight of the air displaced.

Example: The weight of a 10,000 cubic foot balloon, including the basket, is equal to 400 pounds. What will be the excess buoyancy in pounds when the balloon is filled with hydrogen?

The weight of dry air is .0766 lb. per cu. ft.
The weight of hydrogen is .0053 lb. per cu. ft.
Lifting power of pure hydrogen is equal to
$.0766 - .0053 = .0713$ lb. per cu. ft.
Lifting power of hydrogen in general use is only .066

Lifting power of 10,000 cu. ft. of hydrogen in general use is	660 lbs.
Total weight of balloon	400 lbs.
Excess buoyancy	260 lbs.

Then, unless the balloon is held down, it will rise until it reaches an altitude where the weight of the rarefied air displaced is equal to the weight of the balloon. At this altitude it will float along, dropping or rising as it is affected by the atmospheric conditions. If it enters a cool stratum of air, it contracts and descends; if it enters a warm stratum of air or into the sun's rays from under a cloud, it will expand and ascend. The pilot can keep it from descending by dropping ballast, and from ascending too high by opening a valve and allowing some of the hydrogen to escape. In this manner he has a partial control over the direction in which he will go, as he can select different air currents at different altitudes.

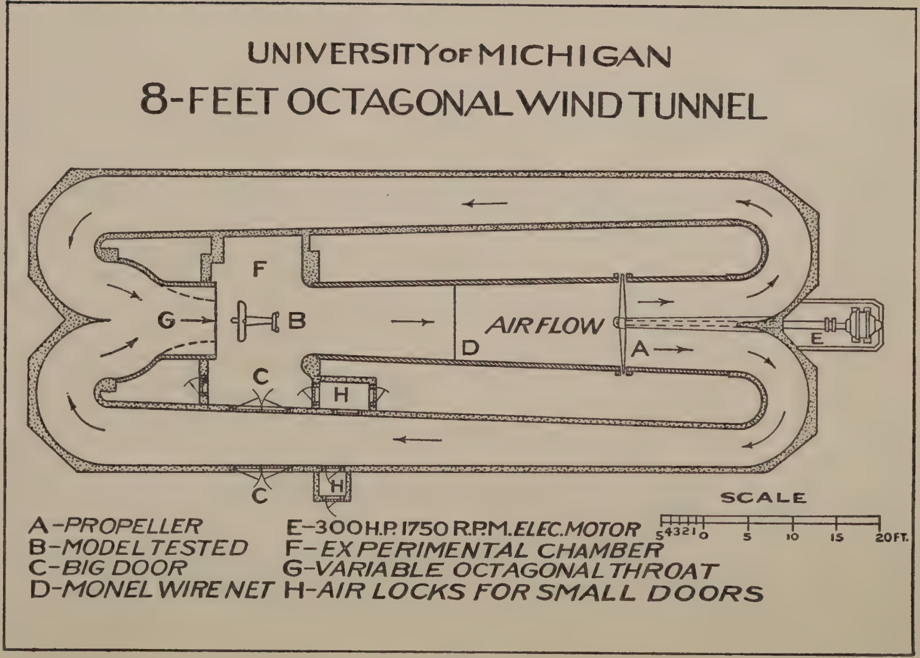
The problem of getting an airplane off the ground is more complicated, as the machine weighs more than the air, and the total lift must be derived from other sources. Just how an airplane weighing thousands of pounds can defy the pull of gravity and go flying through the air will always remain a mystery to some folk. The explanation is simplified when we compare the airplane to an aquaplane or surfboard. Every one has seen pictures of men and women riding these boards, behind speeding motor boats. When the boat stops, the boards sink under the weight of the people riding them.

The boards are rarely over four feet square and vary from one or two inches in thickness. Such a board will not displace much over one hundred pounds of water. The useful buoyant force is equal to the weight of the water displaced minus the weight of the board. Let us assume that a board weighs twenty pounds and that it will, when totally immersed, displace one hundred pounds of water. Then the useful lift or buoyancy that can be used to support a person is equal to $100 - 20 = 80$ pounds. Yet this board when towed behind a fast-moving motor boat will support the combined weight of three people, or over five hundred pounds. The board must be receiving from some source an additional lift of $500 - 80 = 420$ pounds. The dynamic forces set up by the board when towed rapidly through the water provide the necessary lift required to support the weight of the persons riding it. The pull on the rope may be likened to the pull exerted on the airplane by the propeller.

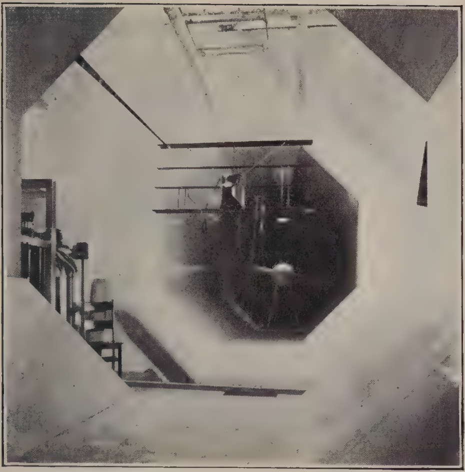
Again, if one holds a cardboard or similar material out of the window of a fast-moving car in such a manner that the flat surface is horizontal, it offers very little resistance. Now, if it is inclined so that the front edge is slightly higher than the rear edge, it immediately offers resistance. The card tries to rise and to move backward at the same time. The force tending to raise the card is called lift, and the force tending to move it backward is known as drag. As we increase the angle of inclination, the lift and drag increase. In an airplane we say we have increased the angle of attack or the plane is climbing at a steeper angle.

It is not necessary to move the card in order to obtain lift and drag, as we can obtain the same forces by holding the card in front of an electric fan. This proves that the air forces on a body are dependent on the relative motion of the air with respect to the body. The discovery of this led to the use of wind tunnels for testing airplanes and airplane parts.

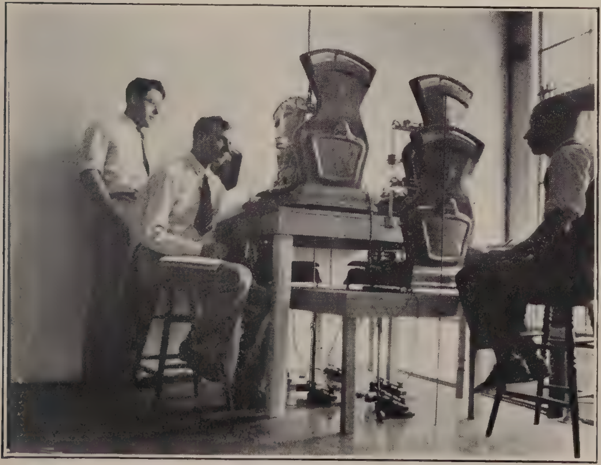
Drawing 1 shows the diagram of the wind tunnel at the University of Michigan. This type is known as the double return tunnel, as it is so constructed as to allow the air to keep in circulation. Because of this, a higher wind velocity can be obtained with less effort. The air is drawn through the experimental chamber by the propeller, *A*, driven by the motor, *E*, and continues around either side and back to the throat. The position of the model is clearly shown in the diagram. The photograph shows the tunnel looking from the throat toward the propeller. The wires supporting the model being tested are connected to the balances shown in the other photographs. These balances measure the forces acting on the model, such as the lift and drag, and by determining the resultant of these we can measure the center of pressure travel and other moments that the designer is interested in. The principle of the tunnel is the same as the Venturi tube used in the physics laboratory. The narrow throat increases the velocity and reduces the pressure at that point. Exact wind velocities can be determined by the use of a mano-


UNIVERSITY OF MICHIGAN
8-FEET OCTAGONAL WIND TUNNEL
AIR FLOW
A
B
C
D
E
F
G
H
SCALE
5 4 3 2 1 0 5 10 15 20 FT.
A-PROPELLER
B-MODEL TESTED
C-BIG DOOR
D-MONEL WIRE NET
E-300 H.P. 1750 R.P.M. ELEC. MOTOR
F-EXPERIMENTAL CHAMBER
G-VARIABLE OCTAGONAL THROAT
H-AIR LOCKS FOR SMALL DOORS

NO. I



WIND TUNNEL, LOOKING FROM THE THROAT TOWARDS THE PROPELLER
Note the model suspended in the experiment chamber



THE BALANCES AND APPARATUS FOR MEASURING THE FORCES EXERTED ON AN AIRFOIL IN THE WIND TUNNEL

meter to measure the static pressure. A motor control is used to keep constant wind speeds.

The double surface wing was an early development; experimenters, trying to imitate the wings of birds, built up with spars and ribs a cambered or curved surface which they covered on one side only. It was not long before they found that these wings were more efficient when covered on both sides. A cross-section of a wing is known as an airfoil or airfoil section. Drawing 3 shows the names of the various elements of two airfoil sections. These sections are described by giving coördinates of points along the upper and lower surfaces. The coördinates are given in percentages of the chord length.

If one is not familiar with the rectangular coördinates system of plotting curves, the procedure of laying out an airfoil section can be explained as follows: The chord length must be first decided on for the given airfoil and this multiplied by the percentages given in the table (see Drawing 2, under the per cent sign). This divides the chord into a number of stations. The next two columns, marked upper and lower respectively, give in per cent of chord the height of the upper and lower surfaces at their respective stations. The stations are laid out from the leading edge, and the points on the upper and lower surfaces, given in columns two and three, are laid out vertically above the chord line at the corresponding stations. By connecting the points thus found we have the curve of the airfoil.

In laying out an airfoil, great care should be taken to get it as accurate as possible. If dimensions are not followed closely, the resultant airfoil will have an entirely

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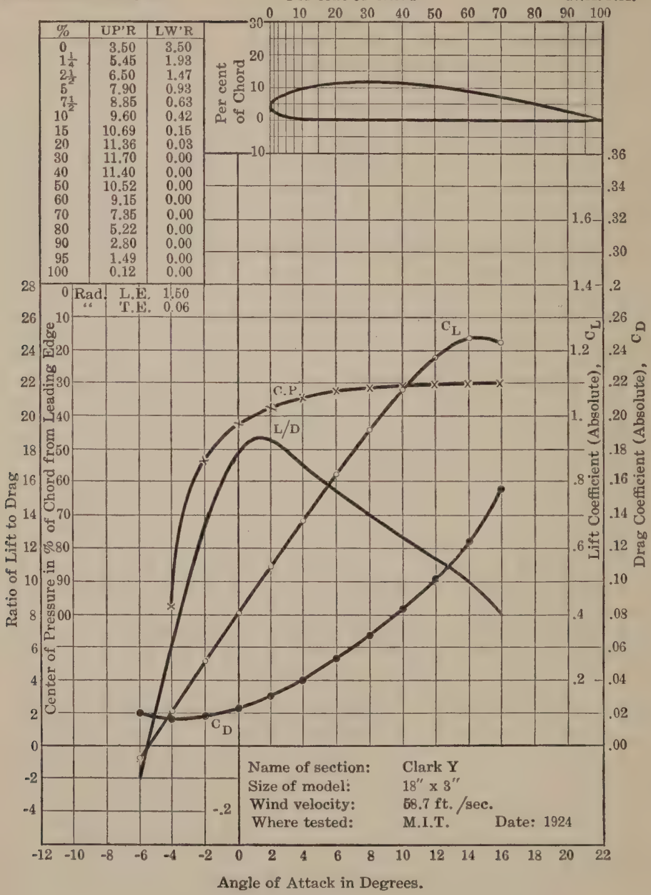


%	UP'R	LW'R
0	3.50	3.50
1¼	5.45	1.93
2½	6.50	1.47
5	7.90	0.93
7½	8.85	0.63
10	9.60	0.42
15	10.69	0.15
20	11.36	0.03
30	11.70	0.00
40	11.40	0.00
50	10.52	0.00
60	9.15	0.00
70	7.35	0.00
80	5.22	0.00
90	2.80	0.00
95	1.49	0.00
100	0.12	0.00

Rad.	L.E.	1.50
"	T.E.	0.06

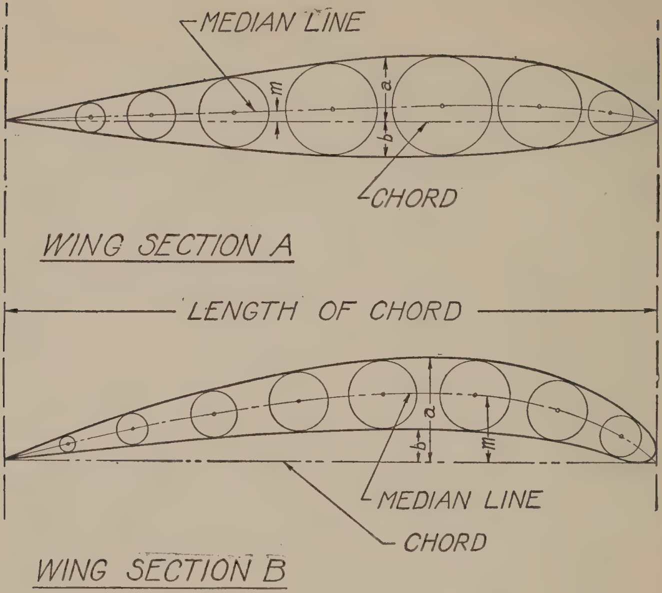
Name of section: Clark Y
Size of model: 18″ x 3″
Wind velocity: 58.7 ft. /sec.
Where tested: M.I.T. Date: 1924

NO. 2

different performance from the original one. If one can obtain the use of a vernier height gage and an angle plate, very accurate work can be done. For models it is the custom first to lay out a template of thin brass, to be used in forming the ribs of the wing. The template may be checked at each station by measuring with micrometers. Some model-builders do not believe in working to such a degree of accuracy, but, if a boy forms the habit of doing all his work with the same degree of accuracy, the results will show in the performance of his model.

The table giving the characteristics of airfoils is a reproduction of reports sent out by the National Advisory Committee for Aeronautics. These reports are printed and sent out by the Government Printing Office. Most of the reports may be had by sending ten cents for each report to the Superintendent of Documents, Government Printing Office, Washington, D.C. A list of reports prepared by the N.A.C.A. may be had by writing to the above address for them.

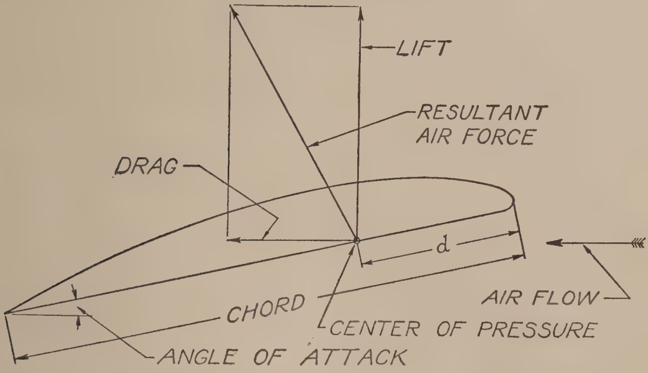
Drawing 3 shows the dimensions of typical airfoil sections exaggerated to bring out the details. The chord is the line that joins the leading and trailing edges. These points can be defined as the two points in the section that are farthest apart. The leading edge is often spoken of as the entering edge and is the foremost portion of the wing. The medium line may be determined by joining the centers of circles inscribed in the section so that they will be tangent to the upper and lower surfaces. The distance *a* shows the maximum amount of upper camber and *b* the



NO. 3. AIRFOIL DIMENSIONS

maximum amount of lower camber. *M* shows the maximum camber of medium line. Tests of airfoils seem to show that the lift of an airfoil increases with the amount of camber given the medium line. Of course other characteristics enter in and have to be taken into consideration when the selection of an airfoil is to be decided on.

An airfoil, or wing section, when held in the wind is acted on by two forces, lift and drag. These forces act on the section at right angles to each other. Lift always acts perpendicular to the air flow and drag parallel with it. Drawing 4 shows a graphic representation of these two forces as they act on an airfoil. The perpendicular arrow represents the lift, and the horizontal, the drag. In an efficient section the lift will always be greater than the drag. If a parallelogram is completed with the two arrows forming two of the adjacent sides, its diagonal will be equal to the combined forces and also point in the direction that they tend to move the airfoil. This line is the vector and is called the resultant of forces.



NO. 4

Just why the airfoil will tend to move in the direction of the resultant rather than in one of the other two directions may be explained as follows: Suppose that, instead of two lines, the arrows representing force and drag were represented by two ropes. Now the drawing shows the length of the lift as twice that of the drag. Let us suppose that the rope representing lift is exerting ten pounds pull directly up while the rope representing drag is exerting a horizontal pull equal to five pounds. Under these conditions the airfoil would not move straight up or back, but in the direction of the resultant, and the pull in this direction would be 11.18 pounds.

The drawing shows the two lines of force intersecting at a point known as the center of pressure. Under actual conditions the lift is not centered at one point, but is distributed along both the upper and lower surfaces.

If we find a point along the chord where these forces will just balance, we have located the center of pressure. If we were to consider only the lift, we could compare it to a teeter-totter with the forces acting down instead of up. The fulcrum or center support, when the teeter-totter is in balance, would represent the center of pressure. This must be moved backward or forward to maintain the balance as the weights change. The center of pressure of an airfoil is located by giving the per cent of chord from the leading edge. In Drawing 3 the position of the center pressure would be d/C.

The angle that the chord of the airfoil makes with the air flow is known as the angle of attack. As this angle changes, the amount of the lift and drag also changes. By careful experiments in the wind tunnel the amount of this change for all the angles of attack, from negative 12° to positive 22°, is found. This change is expressed by a number known as the coefficient. For those who are not familiar with this term, it may be defined as the number or symbol used as a multiplier to express the amount of change under certain conditions. The coefficient usually is placed before the other symbol. In mathematics, when two symbols, a symbol and a number, or a combination of symbols are placed together, multiplication is indicated. Example: $6x$ means 6 times x and AV means A times V.

Lift is also affected by the area of the airfoil and the velocity at which it moves. Tests show that the lift of an airfoil may be expressed by the formula.

$$\text{Lift} = \text{A coefficient} \times \text{Area} \times \text{Velocity}^2$$

Then, if one knows the coefficient of lift at any given angle of attack, the amount of lift may be calculated for any given speed. It is important to remember that the velocity is squared in this formula. For example, let us suppose that the lift of a wing at a given angle of attack is fifty pounds. Now, if we double the speed, we have increased the lift to two hundred pounds or four times. Now if we triple the first velocity, we increase the lift nine times.

The coefficients for lift and drag of airfoils are given in the reports mentioned earlier in the chapter. Space does not permit a thorough explanation of these reports, but one should know at least what the various curves represent. If we turn to the N.A.C.A. reports, Drawing 2, we see in the report of the Clark Y that the various curves are designated by letters. The coefficient for lift is termed C_L and that for drag C_D. This system is part of the Absolute System, which is used in all N.A.C.A. reports. The angle of attack is shown at the foot of the table, while the lift and drag coefficients are given at the right-hand side. Now we can find the lift or drag coefficient for any angle of attack by reading the coefficients opposite the points of intersection of the curves with the lines showing the angles of attack. Example: The lift coefficient for positive 2° is .55 and the drag coefficient for the same angle is .03.

So far we have not made any attempt to explain just why an airfoil gives lift or what causes drag. The explanation of lift which is most often given is that a vacuum is set up on the upper wing surface just behind the point of maximum camber which sucks the wing upward. It is highly doubtful if there is actually a vacuum, but it has been proved that there is an area of low or negative pressure along the upper surface which would have the same effect. It has also been demonstrated that there are areas of positive or high pressure along the lower surface. We know also that as the air flows from the wing it is deflected downward and that the force that deflects or forces the air down has the opposite effect on the wing. This action on the wing is known as lift.

Wind tunnel tests, with special manometers to measure the pressure on the airfoils, show that the greater part of the lift is distributed along the upper surface. The lift at high angles of attack, between twelve and twenty-four degrees, is from four to five times as great on the upper surface as that of the lower, and at angles of attack smaller than this is almost entirely distributed on the upper surface.

Drag is the resistance which the airfoil offers in passing through the air. Air is said to have viscosity; that is, it has a tendency to stick or adhere to any object being drawn through it. If one were to draw an object through syrup it has the same effect. Of course the viscosity of air is nowhere near as great as that of syrup, but it is present and has the same effect, only to a lesser degree.

Most airfoils have a minimum drag at angles of attack near 0°. The coefficient of drag increases as the square of the lift coefficient as long as the lift coefficient increases in proportion to the angle of attack. After this it increases very rapidly.

The *L/D* or the lift drag ratio as it is known, is the lift divided by the drag. The *L/D* is very important in selecting an airfoil. At the angle of attack of zero lift, the *L/D* equals zero. As the angle increases, the *L/D* increases very rapidly, reaching its maximum at about two to three degrees. This is the most efficient angle at which the airfoil can fly, and is the angle of incidence given to most wings. The angle of incidence is the acute angle between the chord of the wing and the thrust line or propeller shaft. The maximum *L/D* in the Clark Y is about positive 1° (Drawing 2).

The last curve shown on the report is the center of pressure travel. This is very important in selecting an airfoil, as it affects the stability of the entire plane. This is easily explained when we think of the lift as a force, not distributed evenly along the airfoil, but acting at one point. If this point moves up close to the leading edge, the nose of the airfoil will tend to rise, thus increasing the angle of attack. When the angle of attack increases, we get an entirely different set of lift and drag coefficients and the center of pressure moves still farther forward. In an airfoil this will continue until the airfoil turns completely over. This is known as unstaple C.P. travel. The center of pressure seldom approaches the leading edge closer than thirty per cent of the chord from the leading edge, for angles greater than zero lift. As a rule this occurs at or slightly under the angle of maximum lift. This is known as the maximum forward position of the center of pressure.

The report shows the per cent of chord from the leading edge on the left-hand side when the center of pressure travel is plotted against the angle of attack. The center of pressure curve for the Clark Y shows that at an angle of attack of negative 4° the center of pressure falls at a point about ninety-seven per cent of the chord from the leading edge, or almost on the trailing edge. As the angle of attack increases, the C.P. moves forward rapidly until at 0° angle of attack the C.P. falls approximately on a point only forty-three per cent of the chord from the leading edge. From this point the curve begins to flatten out and reaches its maximum forward position at an angle of positive 14°.

In selecting an airfoil where stability is desired, one should select an airfoil with a flat C.P. curve between the angles of attack at which the plane is expected to fly. For angles of attack between 0° and 16° the Clark Y/C.P. moves forward about 13 per cent of the chord.

Unlike an airfoil the C.P. for a flat wing, or flat plate, does not move forward as the angle of attack increases, but moves back toward the trailing edge. As the angle increases, the C.P. moves to the rear, having a restoring moment on the plate tending to restore it to its original position. If the angle of the attack decreases, the C.P. moves forward, tending to increase the angle of attack and thus restore it. This type of C.P. is known as a staple center of pressure travel. By using flat wings, advantage is taken of this fact in the indoor models described in this book.

A staple C.P. travel can be given an airfoil by giving the medium line a negative curve near the trailing edge or by designing the airfoil so that the position of the maximum ordinate or thickness is well up toward the leading edge. In both cases, because of other characteristics, these airfoils become very inefficient.

The effect on their performance of changing airfoil dimensions may be summed up as follows:

1. The position of the maximum camber should lie between twenty-five and thirty-three per cent of the chord from the leading edge to obtain the best lift drag ratio, L/D.

2. By increasing the amount of the upper camber, the lower camber remaining constant, we obtain an airfoil with a high lift coefficient. The highest L/D is given by airfoils having an upper camber of from .05 to .12 per cent of the chord. Airfoils having small upper cambers have the lowest drag coefficients. The C.P. curve is affected very little by increasing the upper camber, but the maximum forward position falls farther back on thick airfoils.

3. By adding lower camber to an airfoil having an upper camber of about 12 per cent of the chord gives lower lift coefficients. The L/D increases as the amount of lower camber increases as the drag coefficient decreases.

Wind tunnel tests have shown that thick airfoils may be compared favorably to the thin sections as far as efficiency is concerned. They have a low drag at small angles of attack and give high lift and large values for L/D at increased angles of attack. The thick airfoil has the advantage that all the bracing may be contained internally, permitting a considerable reduction in parasite resistance.

CHAPTER IV

WING CONSTRUCTION

From the foregoing chapter on airfoils, we have learned that the shape of the airfoil is very important in the performance of the airplane. The plan-form or finished shape of the wing is also very important, the shape of the wing tips, the ratio of the spars, lateral dimension, to the chord, and the method of bracing all have to be taken into consideration in the design of the wing. As in the case of the airfoil the resultant of the lift and drag force is known as the center of pressure. In studying the wing, we are interested in its lateral travel. Manometer tests show that this moves toward the tip of the wing at high angles of attack. In building a large ship, the designer should know just how much of a load any part of the wing will be subject to at any angle of attack.

One of the most important factors to be considered in the design of the wing is its aspect ratio. This is the ratio of the span to the chord. If the wing has other than rectangular plan-forms, the ratio will be the square of the span to the area. Wind tunnel tests show that the high aspect ratio gives a slightly higher lift coefficient, while the burble point, or point of maximum lift, falls at slightly smaller angles of attack. The L/D increases considerably with the aspect ratio. This is very important in designing the wing. Designers seldom use an aspect ratio of less than 4.5 or more than 8.5. There are three reasons for this:

a. As the aspect ratio increases, the thickness or depth of the spars will decrease in proportion to the area. In the high aspect ratio the internal structure is very weak, and external bracing must be used to obtain the necessary strength.

b. If the aspect ratio increases, the area of the tail must also be increased to give lateral control.

c. A high aspect ratio means a large span. The housing of planes with large wing span becomes a difficulty that is expensive to overcome.

Wings are often tapered in plan-forms because of definite advantages that have been proved occur with this type of wing.

The advantages show a higher L/D, a higher maximum lift coefficient, and a better climbing ability at high angles of attack. The chief objection to the tapered wing is the increased cost of construction. Each rib must be made from a separate jig.

There are three methods of tapering a wing:

a. Tapering in thickness only. In this case the chord remains the same length at both the tip and root section (center of wing) of the wing.

b. Tapering in chord only. In this case the chord only is changed; the section, because the ordinates are given in per cent of the chord, remains the same throughout the span of the wing.

c. Tapering in chord and thickness.

The tapered wing lends itself to lighter structure and also permits added strength where it is most needed. A complete report on the effect of tapered airfoils may be obtained in N.A.C.A., Report No. 152.

The shape of the wing tip also affects the performance of the wing. Tests show that the negative rake (a curved tip on a wing whose leading edge is longer than the trailing edge) is more efficient. The elliptical follows very closely and because of its appearance is favored by designers.

Airplanes designed to carry heavy loads must have correspondingly large wing area. In a monoplane type of wing, this sometimes is objectionable because of the great span required. By mounting the wings one above the other, we can overcome this to a great extent. Such an airplane is called a biplane. When three wings are used, it is called a triplane. In extremely large monoplanes, the wing structure must be very deep to allow proper bracing unless external bracing is resorted to. As this cuts down the effectiveness of the wing, it is avoided whenever possible. The very nature of the structure of the biplane allows ease of bracing, and permits the use of thin airfoils increasing the speed of the plane.

There are many objections to the use of the biplane, and the designer is always looking for a means to overcome these. We know that the airfoil obtains its lift by deflecting the air downward and that the greatest lift is given to the upper wing near the point of maximum camber. It is easy to see that the air, being deflected downward (down wash) from the upper wing, will interfere with the maximum lift or low pressure area above the lower wing. In order to avoid this, the wings are set one ahead of the other. This is called stagger. The stagger is said to be positive when the upper wing is ahead of the lower and negative when it is behind the lower. Staggering the wing increases the efficiency of the combination, as the high lift area of the lower wing occurs behind that of the upper wing rather than directly under it. The distance between the wings is known as the gap. It is expressed by the ratio of the perpendicular distance between the chords to the chord. The combining of airfoils cuts down the efficiency of the entire wing over that which would be obtained in a monoplane. Because of the necessity of obtaining proper stability by the setting of the wings, thus controlling the center of gravity and because of the importance of unobstructed vision, the designer has to use his judgment in the placing of the wings.

A complete description of the construction of a built-up wing for a model is given in the chapter describing 'The Outdoor Twin Pusher' and it will not be discussed here. Model indoor planes are usually constructed with flat wings because of the extreme lightness that can be obtained, which permits slow speeds, and because of the fact that the flat wing has a stable center of pressure travel. (See chapter on 'Airfoils Sections.')

The most efficient wings that have been constructed use thin flat balsa spars with ribs and tips of bamboo. The shape of these, with the corresponding dimensions, is given on all the indoor plans which are printed in this book. The frame of the wings is covered with Japanese imperial tissue, held in place by banana oil (bronzing liquid) used as a glue.

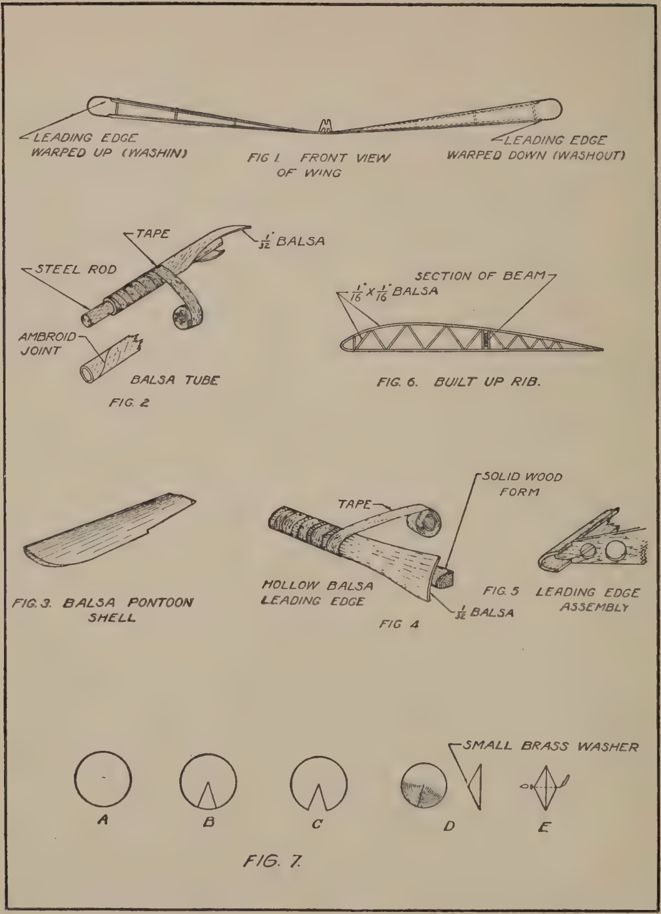
Let us turn now to the drawing of the wing of one of the indoor planes. Notice that the wing is not flat, but forms a very flat 'V.' This angle is called the dihedral angle. Its purpose is to give stability by lowering the center of gravity of the entire plane. You get this angle by bending your wing spars, and in order to get the same angle on each spar, you bend the two while they are in one piece. Lay off on the spar with a lead pencil the positions of all the ribs, being sure to mark the exact center. Now, by holding the spar over the spout of a tea-kettle for a few minutes until it is thoroughly steamed, the spar can be bent very easily. It can also be bent by bending over an open flame. This last method is much more difficult, owing to the possibility of charring and the time that it takes to bend, and should not be used unless the first method is out of the question. Now that the piece is properly bent, you will want to split it down the middle. Do this by laying one half flat on the table, and guiding your knife with a metal-edged rule. Do not attempt to cut through the wood with one stroke. Make several strokes, increasing the depth each time. When the piece is split in two, you have your two bent spars.

You are now ready to bend your bamboo wing tips. These should be studied carefully before the work of bending is started. There is an art to bending bamboo. When it is heated over a flame, it is very pliable, but if you get it too hot, it will char. An alcohol lamp is ideal for this, but, if not available, a candle or gas flame will do. By experiment, you will have to learn to heat it to the right temperature and then bend it while it is still hot. Here is another tip on bamboo: The best part of this material is the shiny side. When you split your small pieces off the big strip, save as much of the shiny side as possible and split away the other side. You never cut bamboo; you always split it. You will find, though, that the split tends to run to one side. When it does that, start a new crack with your knife, closer to the line on which you originally started. Remember, too, always to split off a strip of bamboo that is larger than the finished dimensions call for. After it is bent, you can trim it down to size by splitting small slivers from the side of the strip. The curve should be graceful and should fit evenly into the ends of the spars, as the drawing shows. Notice that the ends of the spars are half lapped, to receive the tips. When your piece is bent, split it into two parts and finish each to the dimensions shown in the drawing. Then glue them in place.

Now you are ready to bend your wing clips. In Drawing 19, just below the right end of Figure 3, note the shape of the two clips. Notice, too, that one clip is 7/16″ higher than the other. The higher one is the rear clip, and serves to hold the wing at an angle to the motor stick. Figure 1 will show you that the front or leading edge of the wing is closer to the motor stick than the rear or trailing edge. This angle, formed by the chord of your wing and the thrust line of the plane (in case of flying-stick models between the chord of the wing and the fuselage), is known as the angle of incidence. The angle of incidence should not be confused with the angle of attack. The angle of incidence is fixed, while the angle of attack is variable, and is formed by the chord and its direction of motion relatively to the air.

The wing is now ready to be covered. Cut a piece of Japanese tissue about 1/2″ larger than the frame of the wing except at the center, where you should cut the paper so that it will fit between the wing clips. When the piece is cut out, coat the center rib with banana oil and place the paper in position upon it. When the oil has dried, paint the frame and the next rib, and with your fingers stretch the paper and hold it in position until dry. Continue in this manner until the wing is covered, taking care every minute to avoid wrinkles. Trim the paper close to the frame by rubbing the edges with sandpaper. After trimming, coat the rough edges with banana oil. This method is used in covering any surface where Japanese imperial tissue is used as the fabric. Japanese imperial tissue can be made waterproof for use on pontoon and seaplane parts by painting with banana oil. Several coats should be given, allowing each coat to dry thoroughly before the next one is applied.

Drawing 5, Figure 1, showing the indoor wing warped out of shape, illustrates the use of washin and washout. A wing is said to have washin when the leading edge near the tip is warped up. This increases the lift because it gives this part of the wing a higher angle of incidence. The wing is said to have washout when the leading edge



NO. 5. WING CONSTRUCTION

is warped down. This reduces the lift, as it decreases the angle of incidence. A wing can be warped in this manner by twisting it carefully in the hands and holding it in this position until it retains its shape. Expert model-builders obtain washin and washout by bending the wing clips out of shape after they are in position. The strain exerted by the wire pulls the spars in the desired position. Washin and washout are given to indoor planes for two reasons. First, to offset the effect of the propeller torque on the plane which has a tendency to cause it to bank and to go into a spiral dive. Second, to aid the torque and the rudder in turning the plane in a smaller circle. In case the plane has a tendency to dive in a spiral as described above, the wing toward the inside of the circle should be given washin and the opposite one washout. By very little practice, one becomes expert in the use of washin and washout.

The drawing in Figure 2 shows how balsa tubes can be made for hollow fuselage sticks. The balsa is planed and sanded until it is only 1/32″ thick. After boiling or thoroughly soaking it, it is wrapped around a metal rod and held in place by a piece of tape or bandage. When dry the tape is removed and the joints carefully ambroided. These tubes are often used for fuselages, as they offer a very strong section and are slightly lighter than the corresponding solid wooden one would be. As the motor is strung through the center, a tube fuselage cuts down the effect of the propeller torque slightly, but prevents the use of slack on the motors which reduces the possible duration.

Figure 4 of the drawing shows the same method being used to obtain a thin balsa leading edge for an outdoor pusher plane. This decreases the weight of the wing considerably, and for mild weather cannot be beaten. Figures 5 and 6 show how the ribs can be butted to the leading edge to form a continuous curve and a lighter type of rib. To construct this rib, a jig or form is made by tacking blocks around the edges of the template. After removing the template other blocks are placed inside of these. In this manner grooves can be formed between the block 1/16″ wide. The steamed balsa is then laid in the grooves to form the outlines and then the braces are glued to these. This type of rib will reduce the weight considerably.

Pontoons can also be constructed by using thin balsa warped over a form. These are then completed by the addition of a 'V' form at the bottom which is covered with Japanese tissue paper and waterproofed by several coats of banana oil.

Suitable wheels are usually a problem to the beginner, most commercial wheels being much too heavy for flying models, and as a rule he has to fall back on flat thin wooden ones. The drawing shows a method often used to construct cone type wheels, which are not only very light, but also extremely attractive. Two round discs of drawing paper are first cut out slightly larger than the desired diameter of the finished wheel. A sector or 'V' is cut from this, as shown in *C*. Then the edges may be folded over and ambroided in place, forming a very flat cone. A small brass washer is then ambroided to the inside of the cone to form a bearing for the axle. Two of these glued together make a very attractive wheel. They can be prevented from coming off the axle by ambroiding a small stream-lined hub or nut on the axle, as shown in *E*.

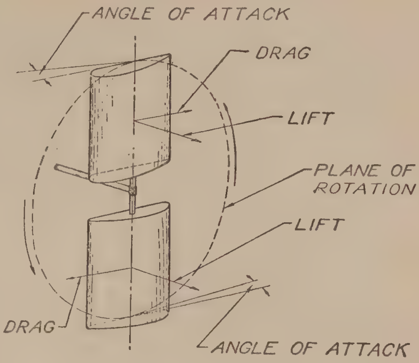
CHAPTER V

PROPELLERS

A boat is driven by means of a propeller or screw revolving in the water. The propeller is driven by the torque or force applied by the engine to the shaft, and literally it screws itself forward or backward. The case of the airplane is very similar. It, too, is driven by a propeller or air screw. All the early designs of air screws were copies of the marine screw. These, because of the different conditions that have to be met by a screw working in air, were never very successful. In 1907 a Polish scientist named Drzewiecki proposed what is known as the 'blade element' theory for the design of air screws. This theory, with a few changes, is the one accepted as the most satisfactory to-day.

If two airfoils, exactly alike, are mounted on a shaft, as shown in the diagram (Drawing 6), and the shaft revolved, the airfoil will be moving relative to the air. This being the case, we have also both lift and drag analogous to a moving airfoil. Study the drawing carefully; notice that the airfoils are set at a slight angle of attack relatively to the plane in which they revolve. The lift will be horizontal and parallel to the shaft, as the airfoils are revolving in a vertical pane. The twisting motion or force applied by the engine to the shaft is called torque, and in the airplane it is this force that drives the propeller.

As explained in the chapter on airfoils, lift is obtained because air is set in motion and deflected downward. In this case the lift is obtained because the revolving airfoils set in motion and deflected backward a cylinder of air equal to the length (diameter) of the propeller. In the case of the propeller the lift is called thrust. The propeller is, therefore, an apparatus for transforming the power or torque applied to the propeller shaft into thrust which is the force that pulls the airplane through the air.

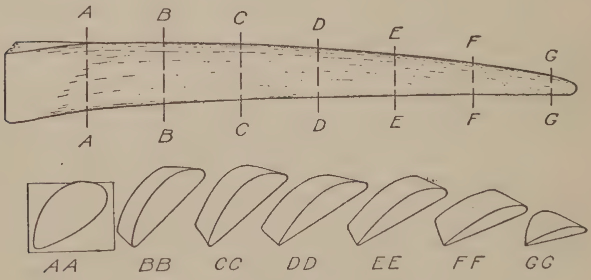


NO. 6. THEORY OF PROPELLER

As the airfoils shown (Drawing 6) revolve, the outer ends move much faster than the parts near the center, as the circumference of the circle in which they travel is much greater than the circles at the hub. The faster-moving parts give more lift while the center parts lag behind; taken as a whole the apparatus is very inefficient. We know that the lift of an airfoil varies as the angle of attack. Now if we can twist the airfoils so that as we near the center the elements will be given a proportionally increased angle of attack, we can equalize the thrust of all the elements along the entire length of the blade even though they are revolving at different speeds.

In a propeller each airfoil is known as a blade. In the

Drzewiecki theory every element of the blade is investigated separately and the amount of twist is calculated by mathematics. Not only is it necessary to give the center sections a greater angle of attack, but, because of the increased strains placed on this part of the propeller, they must be made much thicker. Study the drawing of the cross-sections of a propeller blade (No. 7). This increased strain on the center section is caused by the stresses due to bending moments, centrifugal force, and in the fact that all the lift of the tip sections must be borne by the center sections. In a large propeller the center sections are made so thick that they give practically no lift at all. This is also true in the models where the angle of attack is so great that the burble point has been exceeded and the hub becomes almost a flat plate normal (perpendicular) to the plane in which it revolves. In the real plane the flow of air at the center is interfered with by the fuselage. In some airplanes where the fuselage or cowling is allowed to end rather abruptly,



NO. 7. PROPELLER BLADE WITH SECTIONS

or when large-diameter air-cooled engines are used, this interference, called blanketing, becomes serious, as it cuts down the effectiveness of the propeller and increases the cost of operation of the entire plane. Excessive blanketing must be carefully guarded against in the designing of a large plane.

Similar to an airfoil, the propeller has a leading edge and trailing edge. The aspect ratio of a propeller is equal to one half the diameter divided by the maximum blade width: that is, a propeller with a diameter of eight feet and a maximum blade width of eight inches would have an aspect ratio of 48 to 8 or 6 to 1.

The distance that a nut moves forward on a bolt, in one revolution, is known as the pitch. If we could devise some means by which a propeller could screw into solid guides to prevent slipping, the distance it would move forward in one revolution would be equal to the pitch. This is called the geometrical pitch.

The geometrical pitch is usually stamped on the hub of the propeller and as a rule is calculated for an element of the blade two thirds of the radius from the center of the hub. The ratio of the geometrical pitch to the diameter of the propeller is known as the pitch ratio.

Turning in air, a propeller because of slippage will not move forward a distance equal to the geometrical pitch. The actual distance that it moves forward in one revolution is known as the effective pitch. The difference between the geometrical pitch and the effective pitch is known as the slip per revolution. This slipping is a measure of the efficiency of the propeller. The efficiency of the propeller increases as the effective pitch approaches to the geometrical pitch. The thrust of the propeller depends on the amount of air that is set in motion; it follows, therefore, that the larger the diameter of the propeller the greater will be the mass of air that is set in motion. As the mass of air that is handled for a given thrust increases, the amount of slip decreases.

The speed of the propeller is another factor that must be considered in checking its efficiency. The tip speed is always taken when the speed is given. When the tip speeds exceeds 850 feet per second, the efficiency drops very rapidly. In the case of the model with the rubber-driven propeller we do not have to worry about excessive speeds. Since the efficiency of the propeller depends on the mass of air that can be handled for a given thrust, it follows that the larger the diameter the more efficient will be the propeller. In constructing models we have the advantage of the large ships, as we can design propellers with a diameter equal to one half the span of the wing. Not only does the large propeller handle a greater mass of air, but it also increases the duration of the plane as it slows up the rubber motor.

For model work, the pitch of a propeller may be determined from the block from which it is carved by use of the formula —

$$\text{Pitch} = \frac{\pi D}{W} \times T$$

When $\pi = 3.1416$
D = diameter of propeller or length of block
W = width of block
T = thickness of block

Example: Given a block 11/16″ × 1¼″ × 10″, find the pitch of a propeller carved from this block.

$D = 10''$
$W = 1\frac{1}{4}'' = 1.250''$
$T = 11/16 = .687''$

$$P = \frac{10 \times 3.1416}{1.250} \times .687 = 17.243''$$

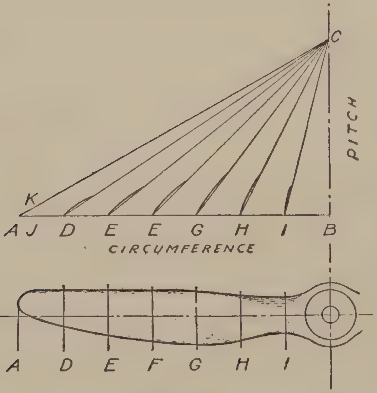
Then the pitch equals 17.243, or for practical purposes it could be called 17.25.

The effective pitch of an indoor endurance model was determined recently in a series of tests by the author. The motor (a double strand of 1/8″–30 rubber 15″ long) was given five hundred turns and the propeller allowed to unwind for thirty seconds to determine just how fast the rubber unwound. This was done a number of times and the average found. An interesting fact about the test was the slight amount of variation found in each test. At no time did the number of turns vary more than two. When the average number of turns that the rubber would unwind in thirty seconds was determined, the plane was flown with five hundred turns given the motor as in the previous tests. The distance that the plane traveled in thirty seconds was calculated by measuring the diameter of the circle and timing the plane while it made four complete turns. Then, by dividing the distance traveled by the number of turns the propeller makes in the same length of time, the effective pitch or distance traveled in one revolution is obtained.

In all the tests the best results were obtained using an indoor endurance plane. The weight of each part was as follows:

Name of Part	Weight of Part
11″ propeller 18″ geometrical pitch	.019 ounce
15″ fuselage assembled	.042
19″ wing with clips	.046
2 strands rubber motor	.054
Weight of model	.161

In five separate tests with this model the effective pitch was calculated as 17.9. This is only one tenth variation from the geometrical pitch, or the slip in this case is almost negligible.



NO. 8. GRAPHIC METHOD USED TO DETERMINE ANGLE OF BLADE FOR A GIVEN PITCH AND DIAMETER

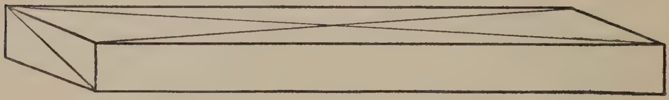
A graphic method used to determine the angle of attack for any element on the blade of a propeller is shown in Drawing 8. The line *AB* is laid off equal to the *D*π or the circumference swept by the tip of the propeller. Line *BC* is laid off equal to the pitch and drawn at right angles to *AB*. Now the line *AB* may be divided into as many equal divisions as the points to be determined on the blade. By connecting these points — seven are shown in the drawing — the angles formed by these lines with the line AB are the angles of attack that should be given to the elements at the corresponding points on the blade of the propeller.

The design of the model propeller can be simplified by using the block method to figure the pitch. If one has a given diameter in mind, he can easily determine the width and thickness of his block by using the graphic method shown above to determine the angle at the tip. The desired width of the blade AK is laid out on AC, and KJ is drawn perpendicular to AB. Then AJ is equal to the width of the block and KJ is equal to the thickness. When the propeller to be drawn is large, the diagram may be laid out smaller, but must be to a scale, such as one fourth or one eighth size.

There are a number of methods used in carving propellers for models. Each has its merits. The type shown below has been used on more record-breaking models than any other, and have proved in this way their effectiveness. These are called the Langley because it is the type used by Professor Langley on his planes.

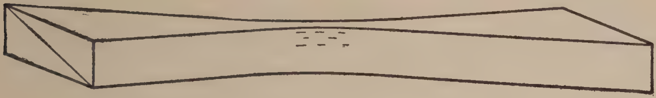
A few years ago almost all the propellers used on models were carved either from white pine, birch, or white wood. This was before the advent of balsa wood, and the construction of the entire model was proportionally heavy. This type of propeller is unsatisfactory when the rest of the model is constructed with balsa, as it becomes nose-heavy. A light medium-hard grade of balsa is recommended for propellers. One should be careful to see that the wood is not cross-grained and that it is free from all checks. Some model-builders prefer to use extremely soft wood, obtaining added strength by giving the finished propellers a coat of banana oil. For flying model airplanes the propeller blades are carved to form a thin flat cambered surface rather than the thick airfoil type used on the large plane. This is necessary in order to cut down weight, as the thick propeller would be much too heavy for the light scientific models now in use. Even if this were not the case, the weight saved is worth more in contributing to duration than the increased lift would be, due to the thicker blade.

Drawing 9 shows the first step in carving the propeller. The block should be carefully trued up to the required size and well sanded. Diagonals are laid out on the wide faces and on the ends as shown. Notice that these end diagonals are drawn in opposite directions. At the intersection of the diagonals, on the flat faces, the hole for the propeller shaft is drilled. This may be done by pushing a pin through the block. Extreme care must be taken to keep the hole straight and at right angles to the faces of the propeller.

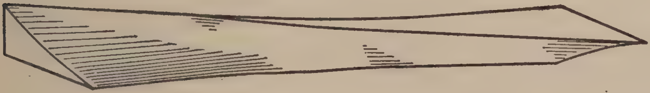


NO. 9. FIRST STAGE PROPELLER CARVING

Drawing 10 shows the next step. Notice how the block has been carved along the diagonals except at the center. This section should be left at least 1/8″ thick until the blades are nearly finished. The face corresponding to the lower surface of an airfoil when used as a propeller is carved first (Drawing 11). Notice that it is not flat, but slightly concave or hollowed out. This is called camber and has the same effect as camber on an airfoil. This camber can be given by sanding carefully after the face is finished flat with the knife. The amount of the curvature may be checked by the use of a steel rule laid across the blade. It should not exceed 1/32″. When this face has been completed the opposite one may be finished by carving until the blades are about 1/16″ thick. The convex side is finished to correspond with the finished side by sanding (Drawing 12).



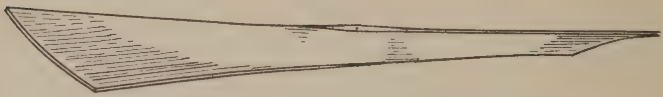
NO. 10. SECOND STAGE PROPELLER CARVING



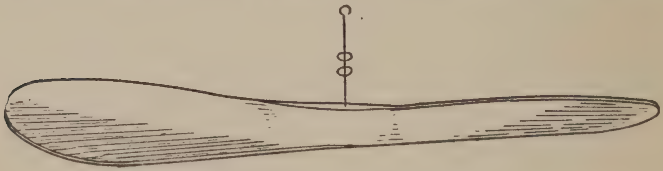
NO. 11. THIRD STAGE PROPELLER CARVING

When the blades are finished, they should be not more than 1/32″ thick, gradually tapering to 1/16″ at the hub. As we know the center section of the propeller is very inefficient and as we are always watching for ways to eliminate weight, we cut out as much of this section as possible. This is done by cutting from the trailing edge a flat 'V' as shown in Drawing 13.

The tips can now be rounded, the edges well sanded, and the propeller is ready for the shaft. This is made from music wire, and when passed through the hub is bent in the shape of a square 'U.' The short end of the 'U' is then embedded in the propeller and the entire hub painted with ambroid to prevent breaking.



NO. 12. FOURTH STAGE PROPELLER CARVING



NO. 13. FINISHED PROPELLER

The method for carving a tractor propeller is essentially the same as described above, with the exception that the shaft is inserted from the opposite side.

A propeller is said to be a right-hand propeller when it turns in a clockwise direction when viewed from the rear of the plane. If it is turning anti-clockwise when viewed from the same position, it is said to be a left-hand propeller. An airplane is said to be a tractor airplane when the propeller is ahead of the main supporting surface, and is said to be a pusher airplane when the propeller is behind the main supporting surface.

CHAPTER VI

THE CARE OF RUBBER MOTORS

In models as in the large airplanes the type of power plant to be used is of prime importance. The designer of a large airplane builds his ship around a motor with a known performance. The model-builder, because of his lack of knowledge of design, builds a ship and adapts his motor to it. This is not such a bad practice, as he can, without much trouble, decrease or increase his available power very easily. Of course this applies only when rubber strands are used for power. However, if one is familiar with the characteristics of rubber, a much more intelligent procedure may be followed with a corresponding increase in performance.

Many model-builders have successfully flown models powered with miniature engines. These power plants include the coil spring or clock works engine, steam engines, compressed air motors, and small gas engines. If one has the equipment and skill to construct engines of this type, they make very pretty models. The greatest source of satisfaction, however, comes in constructing them rather than in flying the finished models, as it is impossible to obtain any duration comparable to that received from rubber-driven models. This is due to the increase in weight with this type of engine over that of the rubber motor. When the weight of the motor is increased, the construction of the entire model must be designed to stand the heavier loads, and the completed ship is proportionately increased in weight. As there are comparatively few boys that have the necessary equipment for constructing this type of power plant, and as most libraries contain a number of books on model engines, none of these will be described in this book.

More energy can be stored up in rubber than in any other known source of power, weight for weight. Because of this, the low cost, and the ease with which it can be obtained, it is very doubtful if rubber will ever be supplanted by any substitute as the favorite motive power for models.

There are many interesting characteristics of rubber with which every model-builder should be familiar, in order to get the maximum from his planes. The available information on this subject is very limited. It is to be regretted that, although many experiments have been made in the past to determine these, very little has been published. At the present time a number of clubs are conducting experiments and comparing results.

Good Para rubber can be stretched to eight times its length, and if it is released within a short period it will return to the original length. If it is kept distorted for any appreciable length of time, it will not return to its original length, but will be slightly longer when released. If rubber is stretched far beyond its elastic limit, its efficiency as a power plant falls off very rapidly in that it becomes what is called dead. This happens also when a motor is left fully wound for any length of time. The rubber loses its power and is sluggish in unwinding. This is the reason that in contests the contestants refuse to wind their motors until the judges are ready to time their flight.

By a number of tests it has been determined that rubber varies in the power or torque which it develops in unwinding proportionately to the number of strands used. Just what the proportion is or what is the formula for it has not been developed. Because of the many variable factors (length and cross-section remaining the same) that affect these tests, such as the temperature, length at which it is stretched, etc., it is difficult to make all the necessary computations, but by the use of empirical formulæ we ought eventually to obtain a fairly accurate table of coefficients.

Preliminary tests seem to show that by increasing the numbers of strands by one half we increase the torque twice; by doubling the number of strands we increase the torque about three and one half times; and if we increase the number of strands three times we get almost seven times as much torque. Example: if we have a four-strand motor, giving a torque of two units, by increasing it as above we should obtain approximately the following results:

Number of Strands	Torque	Turns
4	2	600
6	4	460
8	7	368
12	14	320

The rapid increase in torque is explained by the fact that the large diameter of the motor distorts the outer layers or coils to a much greater degree than with the smaller motor and these rapidly approach the breaking point. Although the torque increases rapidly as we increase the number of strands, the number of turns that it is possible to give the motor falls off for the same reason.

The graph on page 68 shows the results obtained in the first part of an experiment being conducted by the members of the Michigan Model Airplane Club. The object of the test was to find the variations in the breaking point of rubber under different conditions. Two-strand rubber motors of 1/8″–30 rubber 15 inches long were used in the tests. A number of pieces were broken each time and the average taken in order to avoid any error. A 5 to 1 ratio gear winder equipped with a counter was used in winding the rubber.

Fresh rubber was wound until it broke, stretched to 45″, 60″, 67.5″, and 75″ and the breaking points were noted. Then new rubber was wound to 500 turns while stretched to 45″ or three times its length, and allowed to unwind. This is known as prewinding. After the rubber had been prewound, the same tests were made on it as on the fresh rubber and the results noted. The tests were repeated, using rubber prewound at 800 turns and 1000 respectively. The following table shows the average breaking points for each test:

DATA SYMBOLS

P.W. — Number of turns given in prewind
D.S. — Distance stretched in test
A.B.P. — Average breaking point

TABLE 1

P.W. = 0
D.S. = 45″

D.S.	A.B.P.
30	868
45	1190
60	1243
67½	1273
75	1285

TABLE 2

P.W. = 500
D.S. = 45″

D.S.	A.B.P.
30	961
45	1212
60	1273
67½	1257
75	1232

TABLE 3

P.W. = 800
D.S. = 45″

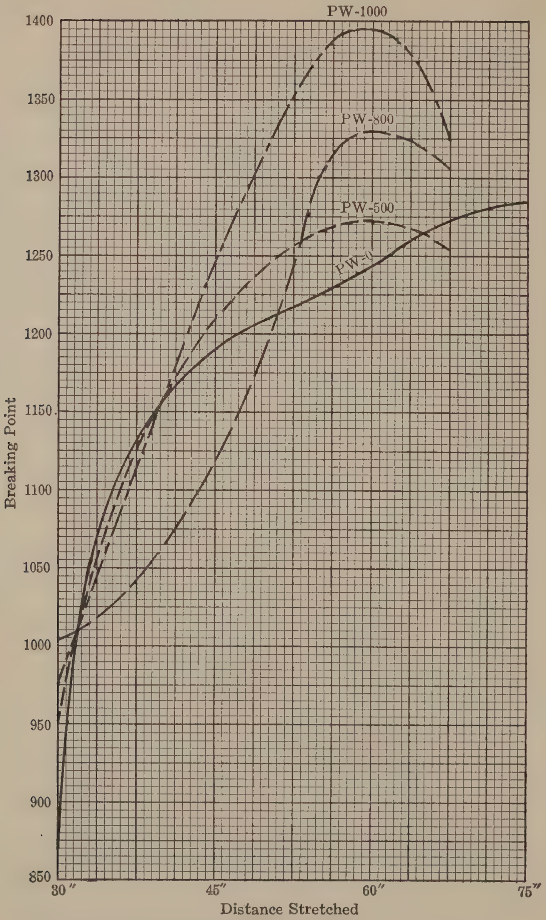
D.S.	A.B.P.
30	1123
45	1123
60	1329
67½	1305

TABLE 4

P.W. = 1000
D.S. = 45″

D.S.	A.B.P.
30	976
45	1247
60	1396
67½	1322

From the above tables we can see that rubber will take more turns without breaking when stretched to approximately four times its length, and that the breaking point drops rapidly when the rubber is stretched in excess of this. The graph shows the breaking point plotted against the distance stretched. Each of the curves represents one of the tables, and the curves are labeled according to the number of turns given in the prewind. Remember that all the prewinds were given to the rubber while stretched



GRAPH SHOWING BREAKING POINT OF RUBBER

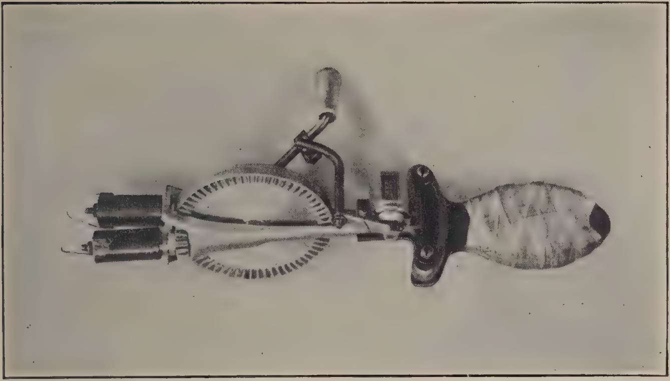
at 45″. The curves show that the average breaking point of a 15″ two-strand motor of 1/8″–30 rubber is at 1396 turns when the rubber is first prewound at 1000 turns while stretched at 45″. This is an increase of 528 turns over that which can be given fresh rubber without any prewinds and stretched to twice its length. The number of turns that can be given unstretched rubber is only about two thirds of that when stretched to twice its length.

Such information is valuable to the model-builder entering duration contests. The tests shown are only a small part of the work to be done. As stated the rubber was all prewound at 45″, and to get complete results the same test must be followed, stretching the rubber to different lengths for the prewind. Accurate results cannot be obtained unless a number of pieces are broken in each test and the average taken.

Of course the results of the above test cannot be taken for motors of different sizes, cross-sections, and lengths. Although the breaking points will be different, the curves will be similar. Many other factors have to be considered before the most efficient conditions for winding this size of motor can be determined. The Michigan Model Airplane Club, in order to determine the effect of stretching and prewinding on the power output, is devising a machine to measure the exact amount of power necessary to keep in the air an endurance model powered with this motor. When the power curve has been plotted, they will measure the effect and plot the power curve for rubber under the above conditions. The intersection of these curves will determine the correct condition for winding motors for these planes. A safety factor has to be allowed in using these tests of about ten per cent; that is, we should not think of giving our motor the full number of turns, but within ten per cent to ensure not breaking the rubber.

When rubber is distorted from winding, to any great extent, the strands stick together. These should be carefully separated after each flight and the rubber allowed to rest. Pure powdered talc or soapstone will help to prevent this sticking as well as help to preserve the rubber. Some model-builders use lubricants to prevent sticking by allowing the strands to slip over one another with a minimum amount of friction. A good lubricant can be made from glycerine, soft soap, and washing soda. A solution of eight parts of water, four of glycerine, and two of soft soap, and one of washing soda makes a good lubricant. The solution should be well mixed and boiled for some time. If it thickens on cooling, more water should be added and it should be reboiled. The liquid can be kept in a bottle and applied with a brush when used. The rubber should be washed in a warm solution of soda and water when being put away. Tests which have been made by model-builders using this solution show that the amount of energy that can be stored up in lubricated rubber is almost twice as much as that in unlubricated rubber.

Of course, other factors that must be considered are the weight of the lubricant, the difficulty in carrying it about to contests, and the mess that it makes of everything in



THE EGG-BEATER WINDER WITH A SPECIAL HANDLE
Notice the counter

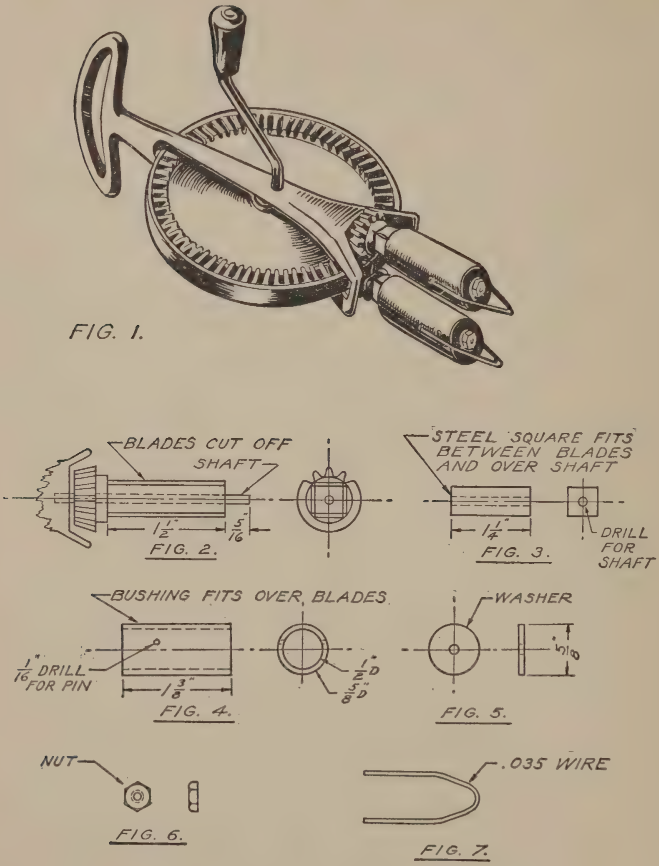
JACK LOUGHNER, NATIONAL OUTDOOR CHAMPION 1926–27, WINDING WILLIAM CHAFFIE'S INDOOR MODEL
Notice how easily the rubber is stretched when the winder is used

handling it. The last two reasons are not serious, and in contests, although undesirable, can be endured. Whether the additional weight is compensated for by the increase in power is the point that should decide whether one should use a lubricant or not.

Light has a very injurious effect on rubber, especially the direct rays of the sun. The author has obtained the best results in preserving rubber by keeping it in an air-tight crockery jug in an even temperature.

As stated above, rubber can be given more turns when stretched to four times its own length. In order to do this, we need to employ some mechanical means of holding the rubber while winding. The egg-beater winder shown in Drawing 14 not only serves this purpose, but, in addition, because of its five to one gears, allows much faster winding. This last is an important factor, as rubber becomes dead very rapidly if kept wound any length of time.

The photograph shows a completed winder made from an aluminum egg-beater with a counter attached. This counter is very useful in winding a plane, as the number of turns given the rubber can be had at a glance. In the drawing (Figure 1) is shown the completed winder without the attached counter. Figure 2 shows the blades or beaters cut off 1 1/2″ from the small bevel gear, except for the center shaft, which is left 5/16″ longer. A 1/8″–32 thread must be cut on this shaft to a point even with the blades. Figure 3 shows a piece of 5/16″ square stock 1 1/4″ long with a 1/8″ hole drilled through the length of it. This steel block slides in between the cut-off blades,



NO. 14. EGG-BEATER WINDER

with the center shaft running through the hole. The cross-section shows how the block fits firmly inside the stumps of the blades. The bushing shown in Figure 4 can be cut from 5/8″ round steel. It is made to slip tightly over the cut-off blades, as you can see from the photograph. A small washer (Figure 5) is then placed over the end, and a small hexagonal nut is attached to hold block, blades, bushing, and washer in place. Do not tighten the nut too much or the winder will be hard to turn. Now the U-shaped piece (Figure 7) is bent from .035 music wire. The photograph shows how it is soldered to the bushing.

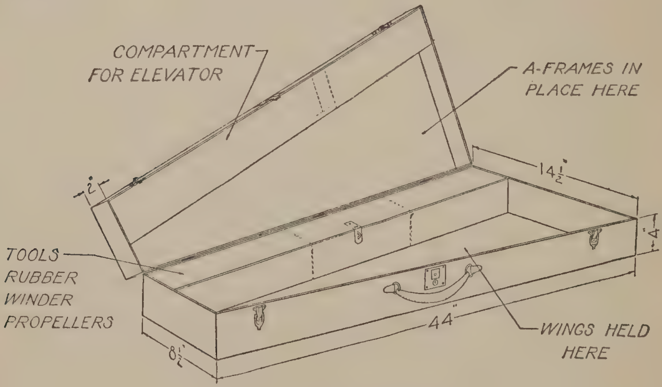
The last operation is the drilling of a 1/16″ pin hole in the bushing. This must be done after the winder is completely assembled. The hole must be drilled to one side of the center so as to miss the shaft and yet go through the square block. A piece of 1/16″ rod is then driven through the hole and soldered at each end to keep it from working loose. Make sure that the winder works freely, and then solder the nut to the shaft to prevent it from ever coming off.

Of course, the process is the same for both shafts, so that the two sets of blades should be cut together and the process should be followed through for the winders on both gears at the same time.

CHAPTER VII

TOOLS AND MATERIALS

Every model-builder should have at least two kits in which to keep his finished models when not in use as well as to provide a means of carrying them from place to place.



NO. 15. OUTDOOR BOX

Drawing 15 shows you the best type of box to build for outdoor planes. Notice that it is wider at one end than the other so that the 'A' frame of your ship will fit nicely into it. Notice, too, that both the lid and the lower part of the box have compartments. Make the sides and ends out of white pine or basswood, 3/8″ thick. The top and bottom may be covered with heavy cardboard or composition wall board.

If a bench saw is available in your neighborhood — perhaps your manual training department has one — you can construct the box in one piece. Use 6″ boards for the sides and ends and nail on your top and bottom covering. Then take your box to the bench saw and rip it through, 4″ from the bottom. This guarantees an exact fit between the lid and the bottom part of the box.

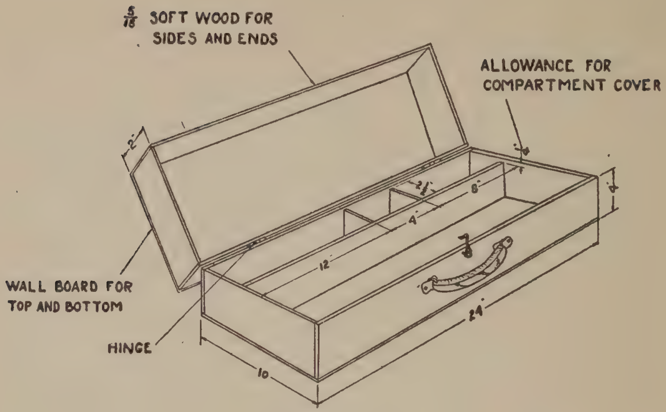
The cover is attached to the bottom by three strong hinges — the box is too long for just two hinges. The lids on the inside compartments are held with strong catches, available at any hardware store. Be sure that these catches are strong enough so that the compartment lids will not spring open allowing your tools to drop out and destroy your fragile wings and balsa frame.

Be sure that you attach your handle to the exact center of the top. Cover the box with black oilcloth, using hot glue. This improves the appearance and makes it waterproof.

The above description with the help of the drawing is sufficient to build the indoor box (Drawing 16) which is very similar, although smaller than the outdoor.

The tools required for model-building are very limited, but when possible should be as complete as may be. A pair of round nose pliers, a small block plane (Stanley 100 or 101 is only 3 1/2″ long), a pair of wire cutters, a good sharp knife, a few old razor blades, and when possible an alcohol lamp make up a very good kit.

For working balsa wood one must have sharp tools; a knife or plane that will not hold an edge is useless. Good pliers may be purchased at any hardware store; the wire


$\frac{5}{16}$ SOFT WOOD FOR SIDES AND ENDS
ALLOWANCE FOR COMPARTMENT COVER
2"
2½"
8"
4"
4"
12"
24"
10
WALL BOARD FOR TOP AND BOTTOM
HINGE

AIRPLANE BOX

NO. 16. INDOOR BOX

cutters must be of good quality or they will not be able to cut piano wire.

Model-building requires the use of strong light material if the models are to be successful with long flights. Prior to the World War, wood, such as spruce, white pine, and birch, was used almost entirely by model-builders. Within the last few years they have used almost entirely the extremely light wood known as balsa.

Balsa is a tree grown in the tropical jungles, in appearance resembling the North American cottonwood. The name 'balsa' is the Spanish word for soft, and was given to the wood because it was used for rafts to float heavy woods, such as mahogany, down the rivers. The botanical name is *Ochroma lagopus*. Balsa is by far the lightest wood known, weighing from six to seven pounds per cubic foot, approximately one half the weight of cork. Although extremely light, balsa has half the structural strength of good spruce, being the strongest wood known weight for weight. Because of these properties, it is far superior to any other wood for model work.

The problem of just what makes the best covering for the airplanes is duplicated in the models. Scale models (non-flying) usually are covered with cloth, either a good grade of linen or Chinese silk being preferred by most model-builders. This can be doped with a good commercial nitrate dope which shrinks and waterproofs the cloth. A coat of lacquer or varnish will give a smooth wear-resisting surface. Berry Brothers, Detroit, Michigan, have completed a great deal of research work on aircraft finishing and have prepared a booklet on the subject which they will be glad to mail to any one on request.

For the 'flying-stick' models, where lightness is essential, we use Japanese imperial tissue for covering. This paper is extremely strong in comparison to its weight and is easily applied. For outdoor models, it can be doped by using a mixture composed of one part of banana oil to five of actone. If the dope isn't strong enough, increase the amount of banana oil.

This commercial banana oil or bronzing liquid is also used as the glue to fasten the Japanese tissue to the frame. It dries very rapidly, holds extremely well, and adds very little weight. Some of the commercial banana oil is very thin. This is useless for models, as it will not serve as a glue at all. Good banana oil is of about the same consistency as castor oil.

Ambroid, which is recommended for use on all models, is the registered trade name for a commercial cement. This cement is waterproof, flexible, tough, and oil-proof when dry. It is about the only adhesive that can be used to fasten the small metal parts to the wooden pieces without the use of thread binding. When a good clean job of ambroiding has been done, the wood will break before the cement will give. Wooden parts, such as fuselage sticks, may be repaired again and again with this material, by butt joining and splicing, and the joints will successfully withstand the enormous strains exerted by the rubber motors.

Some model-builders use reed for forming wing tips and other curved parts of their planes. However, when one becomes expert in bending bamboo, he will prefer this material to any other, as it combines great strength with lightness and flexibility. It is easily worked and can be quickly bent to any shape.

Probably the hardest job for the beginner is the bending of the piano wire parts. Because of its strength, its resistance to bending, it makes excellent metal parts for airplanes. Model clubs should purchase special piano wire cutters for the use of their members, as this wire will very quickly ruin a pair of ordinary cutters.

The wire is sold by gauge number and comes in diameters ranging from .0029 to 0.146 inches. The sizes used most commonly in model work are given, with their gauge number, on page 79.

Gauge Number	Diameter of Wire
5	0.014
6	0.016
7	0.018
8	0.020
9	0.022
10	0.024
11	0.026
12	0.029
13	0.031
14	0.033
15	0.035
16	0.037

CHAPTER VIII

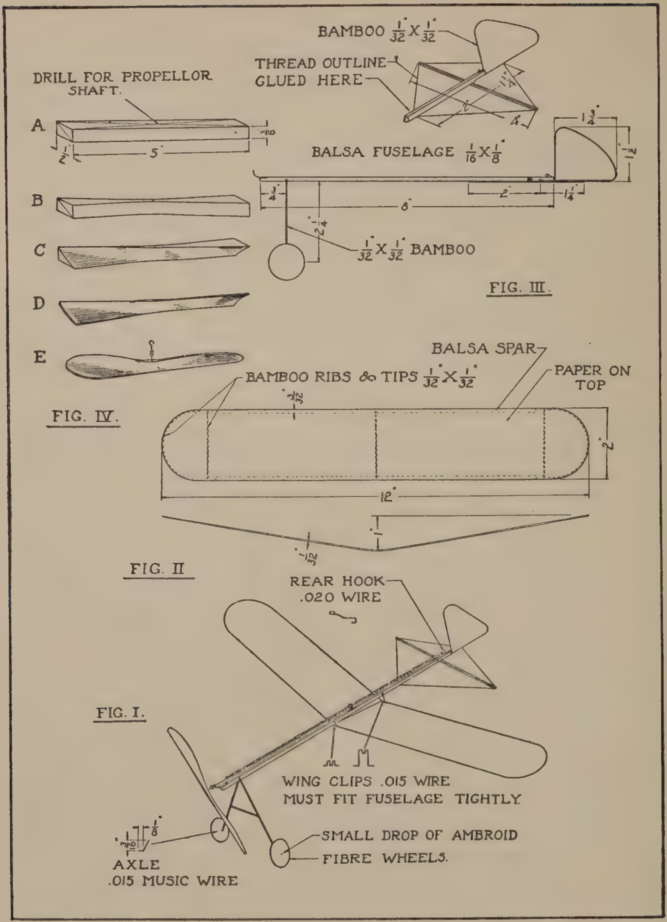
BABY R.O.G.

IF you have never constructed a flying model airplane, the Baby R.O.G. is just the one to start on. This little plane — it has only a ten-inch fuselage — can be flown in an ordinary living-room, where it will circle around and around, or it can be flown in the largest auditorium, where it will go sailing up to the ceiling. It will take off like a real plane under its own power (R.O.G. is abbreviation for 'rise off the ground'), and will come gliding down dead stick and make a perfect three-point landing. When it comes to stunting, it has them all beaten. A good Baby will climb seventy-five feet in one spiral, when powered with 1/8″–30 rubber motor, or it will make as many as nine perfect loops in one flight. The members of the Airplane Model League of America purchased over seventy-five thousand Baby R.O.G. kits during a period of eight months. This is a record for any type of model plane. These kits, as well as the kits for the rest of the planes described in this book, may be purchased from the Airplane Model League of America, American Building, Detroit, Michigan, or from the Michigan Model Airplane Supply Company, 4768 Grand River Avenue, Detroit. As it is impossible to obtain the balsa wood, piano wire, and other special model materials in many communities, these kits are very helpful, as they contain everything necessary to construct the planes, including the metal parts all made up. The League has arranged to furnish the parts separately to those boys who prefer to construct the greater part of the plane themselves.

The Baby R.O.G. is a flying-stick model. Remember, when you start building it, to follow directions carefully and to strive constantly to make the parts as light as the drawings indicate. The drawing (No. 17) shows all the parts with the details clearly shown. If you have difficulty in understanding the directions, refer back to the detail drawing of that part. Do not start work until you have a mental picture of each part and know exactly where it belongs.

The fuselage — the part running from the propeller to the rudder — is shown in Figure III. It is a single stick, eight inches long, planed and sanded to 1/16″ × 1/8″. Be sure not to make it thicker than that, because you will want to keep the plane as light as possible. Balsa is the best wood for the fuselage. It is easy to shape, strong, and only half as heavy as cork. If you prefer, however, you can use any straight-grained soft wood, such as white pine or basswood, although these are heavier and will cut down the time your ship will stay in the air.

Now for the front bearing. That is the small metal part on the front end of the fuselage in Figure I, through which the wire propeller shaft runs. The front bearing is merely a small, flattened brad not more than one half inch long and one eighth inch wide. Drill a hole through the brad, near one end, with a Number 72 drill, and bend the brad in the middle until it is L-shaped. Cement the bearing to the top of the front end of the fuselage stick. If you use ambroid cement, just put a drop of the liquid on top of the fuselage stick. Place the bearing in it and



NO. 17. BABY R.O.G.

hold it there a couple of minutes. After that, it will be securely set, and in another twenty-five minutes the fuselage stick will break before the cement will give.

Next, bend the rear hook from a piece of .016 music wire as shown in the drawing above Figure I. You can shape it with pliers, and you need not bother about the exact dimensions, as long as the entire hook is not longer than one half inch when it is finished. Cement this hook to the top of the rear end of the fuselage stick.

Now bend a wire can from .016 music wire. You will find a picture of one also above Figure I. The can should fit over the fuselage stick and extend about one quarter-inch above it, just high enough so that it will clear a string extending from the propeller shaft bearing to the rear hook. Cement the can to the center of the stick as shown in the drawing.

You will construct the rudder by bending a frame of bamboo and covering it with tissue paper. Study its shape and dimensions in Figure III. It is the triangular part on the rear end of the fuselage stick. Then draw on a piece of paper the outline of a rudder the exact size it is to be. Next, take your stick of bamboo and split off a piece and bend the rudder as directed in the chapter on 'Wing Construction.' If you have trouble with the first one, it is probably because your piece of bamboo is not of even thickness throughout. In that case, try it again with another piece more carefully split. Not so hard now, is it? Be sure, when you bend the frame, that the horizontal strip, along the bottom, extends beyond the frame a quarter-inch.

To attach the rudder to the fuselage, study Figure III. With your knife cut a small groove in the bottom of the fuselage to receive the projecting base of the rudder. Ambroid the two together so as to form a continuous line with the under side of the fuselage. Be sure, too, that the rudder stands up perpendicularly.

To make the tail, first ambroid a stick of bamboo, 1/32″ thick and 4″ long, to the under side of the fuselage, 3/4″ from the end, as shown in the drawing just above Figure III. You will notice that the fuselage is notched to receive this cross-piece. To make the frame of the tail, tie a piece of silk thread around the bamboo base of the rudder, one inch back of the end of the fuselage stick. Tie the thread so that there will be seven or eight inches of thread on each side of the knot. Then stretch the threads taut around the ends of the bamboo cross-piece and forward to the fuselage, at a point two and a quarter inches in front of the bamboo cross-piece. When you are through, you will have a four-sided thread frame, as shown above Figure III. It is fine, delicate work, but not at all difficult.

Now get your Japanese tissue paper and iron it out smooth. If you have used a hot iron, let the paper cool to room temperature before covering the tail and rudder. First of all, cut a piece of the tissue slightly larger than the frame of the rudder. Then paint the bamboo frame of the rudder with banana oil or bronzing liquid. Be sure not to use thin banana oil or it will not hold the paper. Lay the paper on the frame, being careful to smooth out all wrinkles. After you have covered the rudder, trim off the extra paper and coat the cut edge with banana oil to make it stick to the frame. Cover the tail in the same way as you did the rudder, but in this case do not fold the edge of the paper over the silk thread. Simply leave about 1/32″ of paper extending beyond the thread on all sides. You can get a neat edge on the tail by placing a steel edge rule flat on the paper and trimming with a razor blade.

The wing isn't straight, but it is in the shape of a very flat 'V,' as shown in Figure I. The angle formed by the two halves of the wing is known as the dihedral angle. The more pronounced the dihedral angle, the more stable will be your plane — and the less distance it will travel. You had better make your first wing with a fairly pronounced angle, so that your plane will be stable. Later, when you have had more experience, you can try a flatter wing. The flatter wing, you will find, permits your plane to turn more easily, besides giving it more endurance in the air. Another point you will learn is that landing-gear helps to stabilize the plane, so that when a plane is equipped with landing-gear the wing does not need as large a dihedral angle.

To construct the wing, cut out a flat piece of balsa or other soft wood 1/32″ × 5/16″ × 10″ long. Balsa is much to be preferred because it is lighter. A complete description for the construction of this type of wing will be found in Chapter IV. The wing can be lightened considerably by substituting balsa for the bamboo ribs and by using square tips formed from a single balsa rib. This type of wing is not so strong or so good-looking, but is very light and preferred for duration models.

You are ready, now, to bend the two wing clips, of .016 music wire, as shown in Figure I. Be sure to bend them so that they will fit the fuselage stick tightly, or the wing won't hold. Note, too, that the rear clip is 3/8″ higher than the front clip. That is to give an upward slant to the wing, so that the plane will climb. Take care with the two clips, because if this upward slant — called the angle of incidence — is too great, the plane will try to climb too rapidly, and will stall. If it is too small, the plane won't climb. When you have the clips shaped just right, ambroid them exactly in the center of the two wing spars, as shown in Figure I.

The wing is now covered with Japanese tissue. Remember that the neater the paper is put on, the more efficient your plane will be. Study the method of covering wings given in the chapter on 'Wing Construction.'

The propeller is carved from a block 1/2″ × 5/8″ × 5″. In all the models described in this book, we use the method described in the chapter on 'Propellers.' The efficiency of the entire model depends greatly on the propeller, and one should spare no effort to get it as thin and light as possible.

After you have successfully finished and flown your Baby with the five-inch propeller, you can go out after the R.O.G. record by constructing an extra propeller. Use a 1/2″ × 3/4″ × 6″ block for this one. You may have a little difficulty in getting the plane to fly with the larger propeller, but when it does, it should increase your time by at least twenty seconds.

The propeller shaft is shown in Detail *E*, Figure IV.

Study, in addition, Figure I, until you understand just what it is for. Now take a piece of .016 music wire about 1 3/4″ long and pass one end through the propeller, as in Figure IV. Bend the front end into a square 'U' and ambroid it into place. Now bend the rear end, as in Figure IV, so that it will easily engage one end of the rubber motor. Then slip on a couple of small washers, or extremely small beads, to prevent friction between the propeller and the front bearing. Next, slip the hooked end of the shaft through the hole in the front bearing. This puts the propeller into position on the fuselage, as shown in Figure I.

Your motor is a band of .045 square rubber, tied in the middle with a square knot. The band should be long enough to allow about an inch of slack when one end is hooked on the propeller shaft and the other end to the rear hook.

Bend your landing-gear from .016 music wire. The chief requirement of the gear is that it keep the front end at least two and a half inches off the ground, so as to clear the propeller. The top of the gear fastens to the fuselage just as the wing clips do.

You do not need detailed instruction to shape the landing-gear. Nearly every boy varies this part of the plane to suit himself. You can make wheels either of 1/16″ thick fiber or of cardboard. You may arrange either to have the wheels turn on the axle, or have the entire axle turn in a bearing made by looping the bottoms of the supports. Work it out to suit yourself, but be sure to have the front end of the plane at least two and a half inches off the floor.

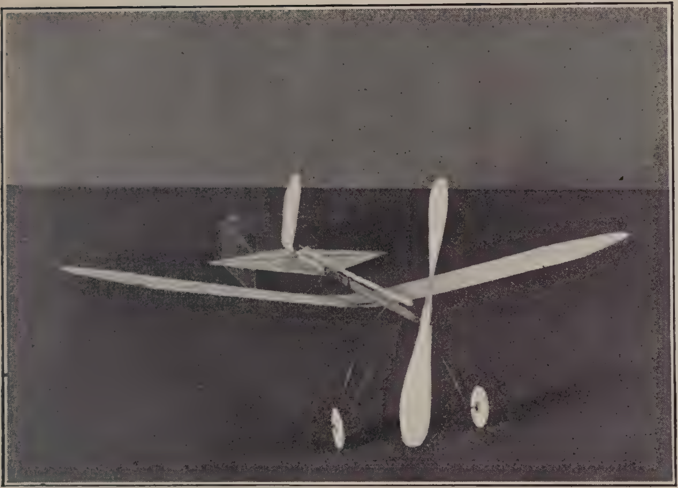
After you have clipped on your landing-gear and attached your rubber motor, you are ready for the test flight. Your work is done and your fun is about to begin.

Before you wind up the motor, let the plane glide from your hand to the floor. If it dives too rapidly, set the wing forward slightly and try again. If the plane tries to climb and then settles on its tail, set the wing back. When the plane glides evenly, it is ready for a flight.

If you are flying outdoors, leave the rudder straight. If you are flying in the house, curve the rudder to the left by holding it close to your mouth and breathing on it while you bend it slightly with your fingers. The amount of bend depends entirely upon the size of the room in which you are going to fly. The plane will not be injured by striking the wall. If you have followed directions the model will be so light that it will careen off without damage.

To wind the motor, hold the fuselage between the thumb and forefinger of the left hand, with the propeller toward you. With the forefinger of the right hand, turn the propeller clockwise. When the rubber strands show a thick row of knots, they are tight enough. Turn the plane away from you, still holding the propeller. When you are ready, release the propeller with the right hand and let go the plane with your left.

Do not chase it or grab it. Just watch it shoot away from your hand, and then circle and climb. In no time at all it reaches the ceiling, hits it, swoops downward, and climbs again. If you have built the plane exactly according to the drawings — which you probably will not



THE BABY R.O.G. FINISHED, USING THE WIRE LANDING GEAR

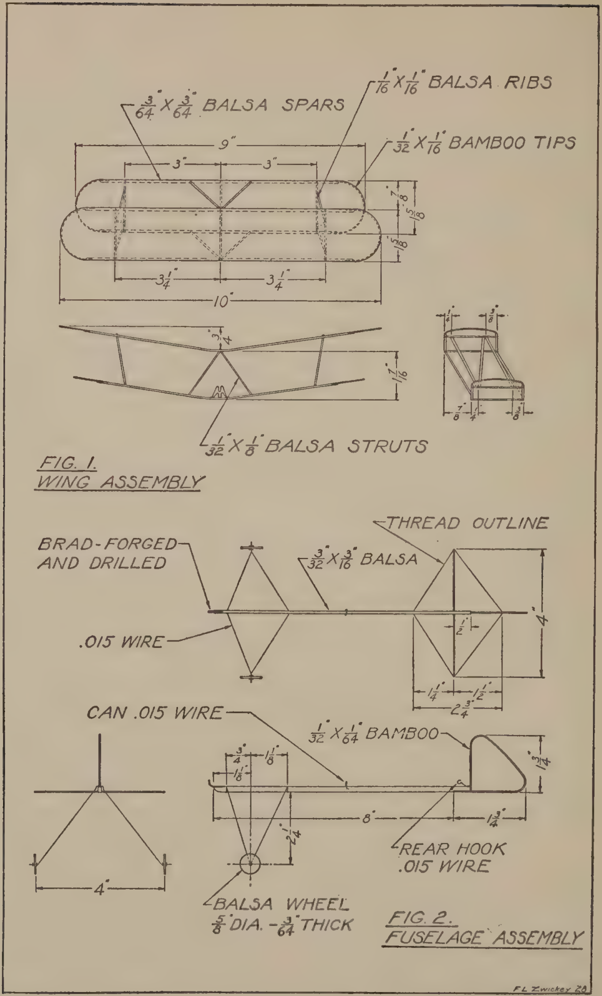
THE COMPLETED BABY R.O.G. READY TO BE LAUNCHED

do on your first attempt — the Baby R.O.G. will stay in the air more than a minute, gracefully circling and then coming to earth. If the first one does not give you a long flight, you have probably made the parts too heavy. In that case, try again. No expert model-builder to-day — no national contest winner — ever built a perfect plane on his first attempt. The fun will come when you construct others, profiting by your experiences to build a model that will perform like an actual ship!

Figure III shows the construction of a baby fuselage with a bamboo landing-gear. Many boys prefer this type over the wire one, as it is much easier to construct and considerably lighter. If you decide to use this type, you will have to cut down the size of your tail surface as shown in the drawing. Both landing-gears have their advantages. The wire one, although heavier, is stronger, and can be taken off the fuselage to be packed away in your kit. The bamboo struts, because they are ambroided onto the fuselage, must be left assembled at all times and take up more room in your airplane box.

Drawing 17–A gives the dimensions for the McCoy Baby Biplane. This plane is very similar to the Baby R.O.G., with the exception of the wing. All the dimensions necessary for constructing this plane are given, and after one has constructed a successful Baby, he shouldn't have any difficulty with the Biplane.

If one cares to, he can use the baby fuselage for this model, although it is much nicer to have one for each plane. The wing is given a positive stagger, the upper is set 7/8″ ahead of the lower. They are connected by



NO. 17-A. THE McCOY BABY BIPLANE

N-type struts of 1/16″ square balsa. The four center spars are placed to allow the fuselage to slip in or out at will. The landing-gear must be of the wire type so that it can be detached when the plane is not in use.

CHAPTER IX

INDOOR PUSHER

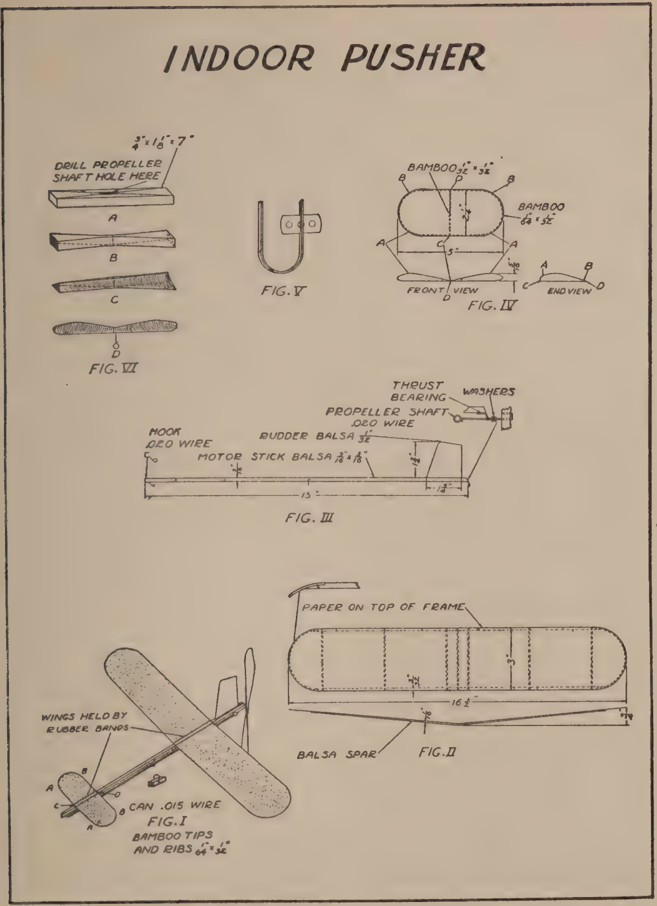
In the early days of aviation, most of the big ships were of the pusher type. Before long, however, this kind became extremely unpopular with aviators, because in a crash the engine, which was situated behind the cockpit, had the unpleasant habit of breaking loose from its moorings, sliding forward, and crushing the pilot. Model-builders share the aviator's prejudice against the pusher.

'It doesn't look like a real ship,' they say.

Maybe not, but it can fly! The Mulvihill outdoor trophy — the official national trophy for duration — has been won *five times with a pusher, and never with a tractor*. The pusher is not only a steady, reliable performer in the air, but it is simple and easy to construct.

Although you may substitute white pine for balsa in any of the wood parts, remember that white pine is heavier and will reduce the flying time of your plane. Balsa is the ideal wood because it is one half lighter than cork — and it is strong.

Before you start actual construction, study the drawing (No. 18). Many of you will be able to build your planes from the drawing alone, without the help of the text. The drawings show the assembled plane, and its five major parts, including the. elevator, wing, motor stick, fin, and propeller. Whenever you get stuck on any part, study its diagram.


INDOOR PUSHER
3/4" x 1 1/8" x 7"
DRILL PROPELLER SHAFT HOLE HERE
A
B
C
D
FIG. VI
FIG. V
BAMBOO 1/32" x 1/32"
B
D
B
BAMBOO 1/64" x 1/32"
2 1/4"
A
C
A
5"
5/16"
A
B
C
D
FRONT VIEW
D
END VIEW
FIG. IV
THRUST BEARING
WASHERS
PROPELLER SHAFT .020 WIRE
HOOK .020 WIRE
RUDDER BALSA 1/32"
MOTOR STICK BALSA 3/16" x 1/16"
1/8
1 3/4"
1 3/4"
15"
FIG. III
PAPER ON TOP OF FRAME
3"
3/32
16 1/2"
1/8
3/4
BALSA SPAR
FIG. II
WINGS HELD BY RUBBER BANDS
B
A
C
D
B
A
CAN .015 WIRE
FIG. I
BAMBOO TIPS AND RIBS 1/64" x 1/32"

NO. 18

Figure II shows two views of the wing; one from the top and one from the side. Notice that it has a span of 16 1/2″ and a chord of 3″. Note that it has spars of balsa, tips and ribs of bamboo, and wing surfaces of Japanese imperial tissue. If you substitute white pine or basswood or balsa, you will want to finish the spars to about one half the size shown in the drawing, so as to save weight.

You will first want to make your two spars from the piece of balsa 1/16″ × 3/8″ × 13 1/2″. This piece, when split down the middle, gives you your two spars. Before you split it, however, you will want to bend it in the middle to form the angle shown in the lower drawing of Figure II. This is called the dihedral angle. The best way to bend it is, first, to mark the piece exactly in the middle and then hold it over the steam for the spout of a tea-kettle. After you have held it in the steam for about a minute, gradually bend it. You can check the amount of the angle by laying one half of the piece flat on the table. If, then, the other end is 1 1/2″ off the table, you have exactly the correct dihedral angle.

Now you must split the piece in the middle to obtain your two spars. To do this without breaking the strip at the bend, lay one half on the table and split it carefully with a sharp knife. Do not attempt to split it in one stroke. Make several strikes, increasing the depth each time. Now split the other half in the same way, and you will have your two spars. Finish them exactly to 1/16″ thick, 3/32″ wide, and 13 1/2″ long. Try to keep the dimensions even throughout, so as to ensure perfect balance. You will want to undercut, or half-lap, the ends to receive the bamboo tips, as shown in the upper left-hand drawing of Figure II.

For your wing tips, finish a 7″ bamboo strip to exactly 1/32″ thickness and 1/16″ width. Take care to finish the strip to exactly the same dimensions throughout, to avoid unsightly bends at the weaker portions.

Bend your strip, shiny part to the outside, over an open flame. Your tips are now 7″ long, which is about 1 1/2″ longer than they need be. Cut them down to the right size and they are ready to be glued to the spars.

Next, make your seven bamboo ribs 1/64″ × 1/32″ × 3″. Glue them to the spars with ambroid cement as shown in Figure II. Notice how the three are placed in the center to withstand the pull of the rubber band that holds the wing in place. Now glue your strips to the lapped ends of the spars, as shown in the same drawing. Make sure, when you glue on the tips, to keep the tips on the same plane with the spars. Do this by holding the ends of the spars flat upon the table when drying.

The frame, now completed, should be coated with banana oil and allowed to dry. This strengthens it.

Your next job is to cover the wing with Japanese imperial tissue. This is described thoroughly in the chapter on 'Wing Construction.'

The motor stick is a piece of balsa 3/16″ × 3/16″ × 15″ coated with banana oil.

To hold your wing in place upon the motor stick, stretch a rubber band across the center of the wing and then push the motor stick through the two end loops of the band, underneath the wing, and the stick will be held tightly against the under side of the wing, as shown in Figure I. Later, when ready for your trial flight, you may want to move the wing backward or forward, to stabilize the plane.

Figure III shows you the motor stick with the rudder, or fin, attached. The same drawing shows you how to bend the front hook from .020 music wire. You will have to get this hook just the right shape by experimenting. Ambroid it to the front end of the motor stick (in the drawing this is the left end) as shown in Figure III. Your rear bearing is the small flattened brad with a hole large enough to receive the propeller shaft drilled through it. In the small drawing between Figures I and III this brad is called the thrust bearing. It is glued to the rear end of the motor stick (in the drawing this is the right end) as shown in Figure III.

The can, bent from .015 music wire, is clearly shown in Figure I and it is glued to the center of the motor stick as shown in Figures I and III.

At the rear end of the motor stick is the fin. This is made from a flat piece of balsa wood 1/32″ thick. It is glued vertically to the top of the motor stick, as shown in Figure III. You may vary the shape and dimensions to suit yourself, although you should keep it approximately 1 3/4″ high and 1 3/4″ wide. Be sure, too, that it is vertical. If it isn't, it will interfere with the performance of the plane.

The elevator, shown in Figure IV, is probably the hardest part of the plane to construct; and it is just about the most important. Study not only the three drawings showing the top, front, and side, but the photographs, as well. Note, in Figure I, how it goes on the front end of the motor stick. Your study will show you that the front or leading edge of the elevator is 5/16″ higher at the tips marked *A* than the rear or trailing edge marked *B*, except at the center where it rests on the stick marked *C* and *D*. Do you get the idea?

Finish the bamboo for the frame of the elevator to 1/16″ square. Perhaps the best method of shaping it is to bend the strip to form one half the elevator. In the top drawing, Figure IV, this would be either the right or left half. Bend the strip over an open flame, just as you did the wing tips.

After the half has been bent to the proper shape, you can split it into two pieces. With a razor blade start first at one end, then the other, splitting it toward the middle (see Figure V). When these halves have been trimmed to 1/32″ square and well sanded, the corresponding ends can be cemented together. While gluing the halves together, the center rib may also be ambroided in place. It is a good idea to put a small block under the point *A* while the cement is drying to keep the frame from rolling, and be sure to see that the trailing edge *BDB* is flat on the table.

Now, referring to the drawing, the leading edge, marked *ACA*, must be bent to form a flat 'V,' the point *A* being 5/16″ higher than the point *C*. The trailing edge marked *BDB* is perfectly flat. This can be done by heating and beginning the bend at point *B* (see the end view

Figure IV), until the point *A* is 5/16″ higher, when the side *DB* is laid flat on the table. Now heating the point *A*, bend it gradually till point *C* touches the table again.

Next the frame is covered with tissue. This is done in the same manner as used in covering the wing.

The elevator is held in place on the front end of the motor stick with a rubber band, just as the wings are.

The propeller for this model is carved from a balsa block 3/4″ × 1 1/8″ × 7″.

Your power is obtained from a strand of 1/8″ flat rubber 30″ long. The two ends of this are tied to form a fifteen-inch band, one end of which is hooked over the end of the propeller shaft and the other end with the knot over the front hook. The strands pass through the can. The rubber motor should be long enough to allow about an inch of slack when it is hooked in place.

You are ready to try your plane. Remember that it flies with the small end — the elevator end — to the front. Give the propeller about three hundred turns and let the plane sail from your hands. If it misbehaves badly, you've probably been careless in finishing your parts to the correct dimensions. Perhaps you have not set your fin correctly upon the motor stick. Maybe your elevator doesn't have enough lift. In that case, you will want to build another, profiting by your experience and working more carefully. If your plane climbs too rapidly, set the wing back toward the propeller. If it climbs too slowly, set the wing forward. Once you have the proper adjustment, your ship will give you a smooth, steady flight that will delight you and astonish your friends. If the plane has a tendency to climb sharply and stall, turn and dive, regaining flying speed only to climb again to a stall; repeating this until the rubber unwinds, it can be made to fly smoothly by giving the wing a negative angle of incidence. This can be done by using a wing clip similar to the one described in the Baby R.O.G. directions. The leading edge should be held about 1/4″ lower than the trailing edge. A small balsa block with a notch cut in the center to fit over the fuselage stick will also serve nicely.

CHAPTER X

INDOOR ENDURANCE TRACTOR

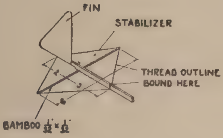
Of all types of model airplane the indoor tractor is probably the most popular. You will find that, although it is a little more difficult to build and possibly a little more tricky to fly than either the Baby R.O.G. or the Indoor Pusher, it cannot be beaten when once adjusted properly and flying. You who have successfully built the two planes mentioned above will have no trouble in constructing this plane. If you haven't made the other two, it would be very advisable to construct them before attempting the endurance tractor.

This is the plane to build for demonstrations or to enter in the indoor contests. It was with a plane built from the plans below that Aram Abgarian established a new world's record of 207 minutes for indoor models.

White pine, basswood, or other very light woods may be substituted for balsa parts. If you are planning on entering a contest, this is not advisable, as balsa wood is much lighter than any other wood, and therefore increases the flying time of the plane.

Before starting to build the plane, be sure to study the drawing (No. 19) so that you have a definite picture of how your finished plane should look when completed, as much time will be saved and better results obtained if mistakes are prevented instead of corrected. Figure I shows the completed plane ready to fly, with all the parts in place, and

INDOOR ENDURANCE TRACTOR



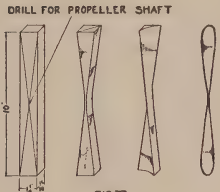


FIG. IV

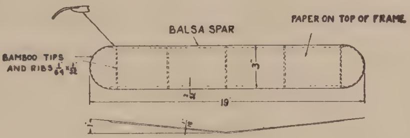


FIG III

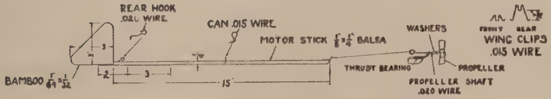


FIG. II

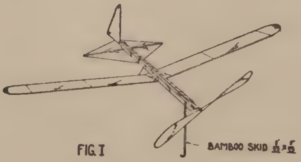


FIG. I

NO. 19

should be referred to each time before starting any of the details. By doing this you will prevent many mistakes and the parts of your completed plane will fit together better when finished.

The motor stick and tail group are shown in Figure II. Your motor stick should be straight, well sanded, and when finished not over 1/8″ × 1/4″ × 15″. When the work is done carefully, this size may be reduced to 3/32″ × 3/16″ × 15″, but in that case, if the stick is not almost perfectly made, it will break under the strain of the motor when wound. For this reason it is not advisable to reduce the sizes shown in the drawing, except for contest models. Expert model-builders use micrometers to measure the thickness of the motor stick in order to get it uniform; in this way they can check it for size within one thousandth of an inch. If any other wood is substituted for balsa, the stick can be made much smaller, but will still weigh much more.

Remember that you are building this plane for endurance and that weight cuts down duration. If you can remove any surplus wood without weakening the parts, you have increased your duration. Tapering the stick toward the ends on the top and bottom and pointing the front of the stick under the thrust bearing are methods used by some boys. These little kinks may seem trivial and not worth while, but often are all that stand between the winner and the loser.

You can now fasten in place the metal parts, thrust bearing, rear hook, and can, as shown in the drawing. The thrust bearing is made from a small flattened brad.

You can flatten a 3/4″ brad by laying it on a flat piece of steel or iron and tapping it with a hammer. Do not flatten the brad any thinner than a 1/32″ thick, or it will bend. Now you can drill a small hole in the end using a Number 76 drill for the propeller shaft. When drilled, the bearing should be bent as shown in the drawing, being very careful not to break it while bending. The angle of the bend must not be too sharp, as this weakens the thrust bearing and allows the propeller to rub against it when turning. The hole for the propeller shaft when in place on the motor stick should never be over 1/4″ from the stick, just high enough to allow the rubber to unwind without rubbing against the stick.

Now you are ready to make the rear hook. This must be made of music wire, .020 being preferred; any other wire will bend under the strain of the rubber or if strong enough will weigh far too much to be considered. A pair of round nose pliers will be found handy in making the hook. You will notice how the end is bent over the rear end of the motor stick in order to give it a firmer hold. When you are bending your hook, be sure to make it so that it will lie close to the stick, just far enough away so that your rubber will not rub. If you have a high thrust bearing and rear hook, the rubber will bend the motor stick and possibly break it; if you make them too low, your rubber will not unwind freely.

The can is made of .015 music wire and should be made as shown in the drawing. The diameter of the loop should be about 1/4″ and placed so that it will just clear the rubber on all sides when wound. These parts can now be cemented in place on the motor stick in the position shown in Figure II. When you use ambroid cement, binding with thread is not necessary, as the cement will hold the metal so firmly that the wood will break before the fittings pull off.

While the cement is drying, we can get the parts made for the tail group. If your paper is at all wrinkled, you had better iron it out flat before you start on any other parts, as you will want to let it stand a couple of hours after ironing, so that it will regain moisture. Otherwise it will warp your surfaces all out of shape.

The detail drawing of the fin and elevator, shown at the left-hand side of the drawing above the rear end of the motor stick, shows how these parts are made and assembled. In a full-sized airplane we have a fixed vertical fin, and fastened on this by means of a hinge is the rudder. The fin gives stability in flight, while the rudder gives directional control exactly as in a boat. In our model, we have only a fin, but curve this slightly when completed to take the place of a rudder. It is composed of a triangular bamboo frame covered with Japanese tissue.

Now then let's bend the fin. This is bent from a piece of bamboo 1/32″ × 1/16″ × 11″. An easy way to get the shape you wish is by first drawing it on a piece of paper and then bending it to fit the drawing. The base and height of the fin should be three inches. The shape may be varied to suit your own ideas. Of the numerous shapes tried out, the one in the drawing has proved most satisfactory because of its strength and the ease with which it may be warped. The finished frame should form a triangle with the base at right angles to the vertical or front side and should extend 1/2″ under the rear end of the motor stick in a groove cut to receive it. Note in the drawing how the motor stick has been cut away to allow the base of the fin and the under side of the motor stick to form a straight line. Your fin is now ready to be split. You are probably wondering why we didn't finish the piece to size before bending. There are several reasons for this: first, bamboo is less likely to crack or bend sharply when larger pieces are used; second, the small pieces are more apt to char and spoil the piece, and finally, many boys bend up large pieces, and then whenever they need an extra fin all they have to do is to split one off. The fin when finished should be 1/64″ × 1/32″ thick, but it is wise to split the piece at least 1/32″ wide and then work it down to size.

Many model-builders raise the rear end of the fin about 1/16″ to set it at an angle to the motor stick, in order to give a negative angle to the stabilizer which is fastened to the fin. This they claim gives the model a better glide and helps it in flying. I should not advise any except experienced model-builders to try this, as some of the best records have been made without any angle at all on the stabilizer.

The best way to line up the fin with the motor stick is to ambroid it in place and then lay it on a flat surface, such as a table-top. With a tri-square set on end, you can check the fin as to whether or not it is perpendicular to the table.

While you are waiting for the fin to dry, you can finish the propeller blocks to size and draw your lines on the top and bottom as shown in Figure IV.

When this is done, you can finish the tail group, as the fin will be dry enough to work on. The stabilizer (see Figure II) is a four-sided figure formed by stretching a thread from the base of the fin around the ends of a bamboo rib and back to the motor stick, where it is fastened in place. This frame is covered with Japanese imperial tissue.

Your rib or cross-member should be split from a piece of bamboo six inches long to 1/32″ square, making sure that the piece is perfectly straight and uniform the entire length or your plane will not fly smoothly. If you have trouble with the first one, try another, and you'll find that it isn't so hard after all. When this piece is finished, it is ambroided to the under side of the motor stick. You should study Figure II carefully; notice how this stick is set in a notch cut 3/4″ from the end of the motor stick so that the under sides of both sticks are exactly flush or even. This allows your stabilizers to lie perfectly flat.

The thread outline should be put on next. Here's the way it is done. A piece of thread 20″ long is tied to the base of the fin 2″ back of the cross-member so that the loose ends will be each about 10″ long and the knot will be on the under side of the fin. Now you can stretch these ends out around the end of the cross-member — not too tight, but tight enough to prevent any slack. Then tie the end to the motor stick 3″ in front of the cross-member, passing the thread under the motor stick and then over so that the thread will run to the under side. This allows the whole outline to lie flat with the bottom of the motor stick. To hold your thread in position, paint the points of contact with ambroid.

Now you can paint the whole outline, fin, and motor stick with banana oil. This strengthens the stick and helps to stick the paper to the frame. While this is drying, you can cut out your paper for the fin and stabilizer. This should be cut to about 1/2″ larger than the surface to be covered, to allow for trimming. Next give your fin another coat of banana oil and lay the paper flat on the fin holding the stick in your hand with the fin in a horizontal position. You shouldn't have any trouble with this operation, as the surface to be covered is so small that the paper seldom wrinkles. When the banana oil is dry, trim the paper close to the frame, either by rubbing with fine sandpaper or cutting with a razor blade. The next job is the covering of the stabilizer. First you paint with banana oil the entire thread outline, including the cross-member and the parts of the fin and motor stick which touch the paper. Now, holding the motor stick upside down, lay your paper in place, making sure there are no more wrinkles. When dry, trim it carefully with a razor blade, leaving at least 1/32″ of paper on the outside of the thread. Never fold the paper over the thread, but leave the edge as it is cut. If you have a metal-edged rule, it will help you to guide the razor blade in a straight line. Another coat of banana oil around the edges of the paper will fasten all rough edges to the frame and completes the job.

You are now ready to start your wing. Figure I shows how this fits to the motor stick by means of wing clips, and Figure III shows a detail drawing with all dimensions.

The first thing to do in constructing the wing is to make the spars. These are made from one piece of balsa, and it should be finished accurately to 1/16″ × 3/8″ × 16″. Many boys make their spars slightly thicker in the center and taper them toward the tips, but, as it is hard to get them the same on both sides, it is not advisable to do this on your first plane. Notice that the wings are not flat, but are bent to the shape of a very flat 'V.' This angle is called the dihedral angle and is used to give lateral stability. This also lowers the center of gravity, and in this type of plane a low center of gravity increases the ease with which it can be flown even in comparatively rough weather. Another way to get lateral stability is by increasing the area of the fin. Both this method and the use of the dihedral angle prevent side slipping. In order to get the same angle on both, they should be bent while in one piece. Probably the easiest way to do this is to steam the piece over the spout of a tea-kettle for a few minutes and then bend it at the center. Check the angle by laying one side flat on the table and if the other end is exactly two inches above the table your angle is just right. Other methods used in getting this angle are to cut the spar at the middle and, with the outer ends resting on 1″ blocks, to form a 'V,' joining the two by ambroiding. Still another is to bend them over a flame as in the case of bamboo, but this is rather difficult. Assuming that you used the easiest method — that is, steaming — you are now ready to split the spars apart. This can be done by laying them flat on a table, cutting one side at a time, and with a metal-edged rule to guide your knife gradually, splitting lengthwise down the center to form two spars. Do not attempt to cut through with one stroke, but by repeating gradually split your spars apart. Now take your two spars and finish them to 3/32″ wide.

Next you'll want to bend the wing tips. These are bent from a piece of bamboo 1/32″ × 1/8″ × 6″ and this is then split to form two tips. In this manner both tips are identical. The curve should be graceful and swing evenly into the ends of the spars, where they are half-lapped as shown. This prevents any lumps where they meet and makes an extremely strong and neat joint.

The five ribs can now be made and cemented in place. These are made of bamboo and finished to 1/64″ × 1/32″ × 3″ and evenly spaced about 3 3/4″ apart as shown in the drawing.

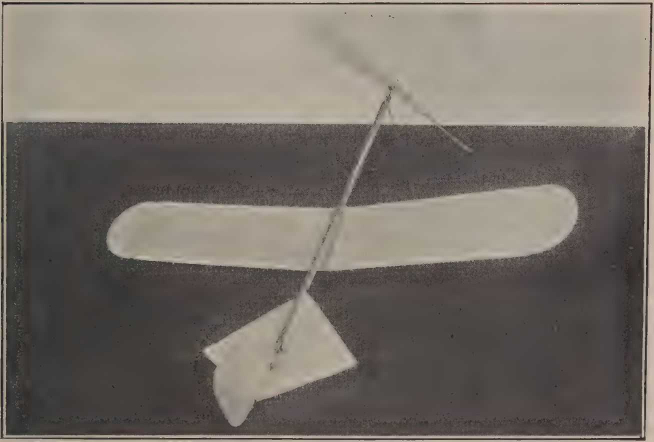
You are now ready to bend your wing clips. Note how they are made in the drawing, the rear clip being 7/16″ higher than the front clip. This is to hold the wing at an angle to the motor stick, called the angle of incidence. This is plainly shown in the drawing, Figure I. Without question the clips are the parts of the whole plane requiring the most particular care. Once these clips are in place, they cannot be adjusted to any extent without warping the wing, and unless they fit the motor stick snugly, your wing will persist in coming loose. When finished and ambroided in place, they should hold the wing square with the stabilizer.

The wing is now ready to be covered. The paper should be cut out about 1/2″ larger than the wing except at the center, where it can be cut to fit between the clips. The paper is fastened to the top of the wing with banana oil and the same method used as in covering the tail surface. The propeller should be made of balsa, as any other wood makes such a heavy propeller that it is almost impossible to fly it unless the diameter is reduced to about 8″, and this, of course, cuts down the duration. Beginners will do well to practice on white pine or basswood before starting on the balsa block. Be sure to finish the block to 11/16″ × 1 1/4″ × 10″ before laying out the diagonals. When you have built and flown several planes, try an 11″ propeller in place of the 10″.

The assembled plane (Figure I) shows a bamboo skid fastened to the front of the motor stick. You will not need any directions for making this, as it is very easily seen how it is made. This skid is not necessary, but when used it protects the propeller and also helps to ensure stability. This completes the plane.

And now the fun begins. The rubber motor is a 1/8″ rubber strand with the ends tied in a square knot to form a 15″ rubber band. If a winder is used, we add a small 'S' hook to hook the rubber to the winder, and, when wound to the hook, the rubber is placed so that the knot will be at the rear hook and, passing through the can, is hooked to the propeller shaft. Before winding, let the plane glide from your hand to the floor. If it tries to climb and settles back on the tail, move the wing back, if it dives to the floor, move the wing forward; when it glides evenly it is ready to wind.

CLARENCE CHAMBERLIN, NEW YORK-TO-PARIS FLIER, EXAMINING THE INDOOR TRACTOR



LOOKING AT AN INDOOR TRACTOR FROM THE REAR

To launch the plane you should hold it in your right hand by the motor stick and with the left hand prevent the propeller from turning. When you are ready, release the propeller with your left hand and the plane with your right. If you have followed directions carefully, the plane will soar up, climbing rapidly in circles until it reaches its ceiling, where it will continue to circle until unwound, and then it will glide in large circles back to the floor.

If the plane makes too large a circle or flies in a straight line, bend the rear end of the fin slightly in the opposite direction to that in which your propeller turns. This may be done by holding it close to your mouth and breathing on it while you curve it slightly with your fingers.

Remember that this plane when properly constructed will be so light that it will not injure itself when bumping the wall or any other object; and that this plane has twice won the National Indoor Trophy as well as breaking the world record for indoor flying by making a sustained flight of 207 seconds.

If you've built your tractor according to directions, you have a plane that flies smoothly and well. Probably you've timed it — have found that it will fly two minutes or more. If you have done as well as that, you can perform all sorts of interesting stunts with your tractor. If it follows a path resembling an ocean wave or a series of connected Zs, you will want to improve it until it behaves. Or you may profit by your very valuable experience and build another.

There's something to be said for both plans. If you try to rebuild your tractor, you are sure to find out what was wrong with it in the first place. Maybe your motor stick was too heavy, maybe your wing spars were not well balanced, maybe your propeller was too thick or badly carved, or maybe your fin was set crooked. Any deviation from the standard will affect the flight of your tractor, and probably, with a little extra work, you can convert it into a first-rate ship.

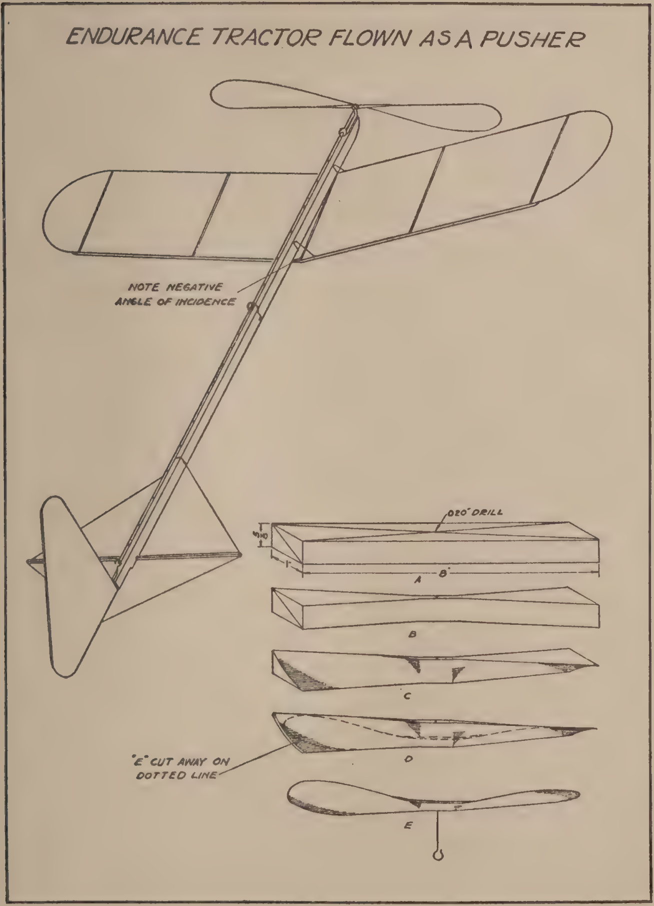
Now you have a tractor that will rise slowly in large circles until it reaches a height of fifty feet or more, and will then come down slowly to a perfect landing. Here are the things you can do with a tractor like that:

1. You can turn it into a pusher that should fly from sixty to seventy-five seconds.
2. You can try it out for altitude as well as duration.
3. You can determine its speed and the distance it will travel.
4. You can make it loop-the-loop, turn in short circles or fly straight, or you can build a landing-gear so that it can rise from the ground.

Turning your tractor into a pusher isn't hard at all. Just move your wing toward the propeller, wind your propeller *the other way*, and launch your pusher with the tail to the front! (Drawing No. 20.)

It may not fly perfectly the first time. If it climbs too rapidly, set the wing back toward the propeller; if it climbs too slowly, set it forward. Give the propeller at least three hundred turns — to the left as you look toward the tail, remember — and your transformed indoor tractor will give your indoor pusher a contest!

Of course, the propeller on your tractor can't be ex-


ENDURANCE TRACTOR FLOWN AS A PUSHER
NOTE NEGATIVE ANGLE OF INCIDENCE
.020" DRILL
5/16
1"
8"
A
B
C
D
"E" CUT AWAY ON DOTTED LINE
E

NO. 20

pected to be as efficient as a pusher propeller. Its blades are cambered out a little, you recall, so that the propeller will get a better hold on the air as the edge cuts its way through. Naturally, when you wind up your propeller the other way, this 'camber' helps the air to slide off the blades — it's a hindrance instead of a help. So, if you want your tractor to perform as well as a pusher, you'll make a pusher propeller for it.

The propeller for the transformed tractor should be carved from a block 5/8″ × 1″ × 8″ in size.

Don't forget, when you put this pusher propeller on your transformed tractor, that it is a 'right-hand' propeller. That means that it must turn to the right to push your plane, and therefore you must turn it to the left to wind it. With this pusher propeller your improvised pusher should fly at least half as long as it will fly as a tractor.

If you restore the original propeller to your tractor, and reset the wing so that it will fly with the wing to the front once more, you can try out your tractor for altitude. A well-made tractor will spiral up to a hundred feet, if you can find a building with a ceiling as high as that. It's fun to time the interval it takes your plane to get to the ceiling, just to find out what its climbing ability is.

Even though your tractor flies in a circle, it is not hard to find out how far it will fly. Suppose you have the fin set so that your plane will fly in a circle with an average diameter of thirty feet. (A good model will follow the same path around and around.) If the diameter is thirty feet, then the circumference is 30 × 3.1416 (pi), or 94.25

feet. Now time your tractor during several flights, until you have a good average figure representing the number of seconds your model takes to fly once around its circle. Now, knowing the distance represented by the circle and the time required to fly it, you can find the 'feet per second' speed of your plane. Once you have done that, all you have to do to find the distance your model will fly is to multiply the number of seconds it stays in the air by the number representing the speed.

For example, suppose your tractor flies around a circle 30 feet in diameter in 15 seconds. That means it is traveling about 95 feet in 15 seconds, a rate of 6 1/3 feet a second. Now suppose your tractor stays in the air 120 seconds. To get the distance it flies, multiply 120 by 6 1/3, and you get 760, the number of feet the model flies.

As for making your tractor loop-the-loop, you can do that by putting the wing far forward and winding up your rubber until you have a double row of knots. If you have enough motor power — perhaps you will have to add a double strand of rubber to your motor — your ship will climb steeply, turn over on its back, and describe a pretty loop!

By experimenting with washin and washout on the wings, you can make your tractor fly right or left or straight, although you may need to warp the fin to help. (You have already learned that by bending up the leading edge at one tip, you give that side of the wing 'washin,' and by bending down the leading edge on the other tip, you give that side 'washout.' You can do this wing-twisting with your fingers, without heat. It helps to control the direction in which your plane flies!)

Then, if you like, you can make a landing-gear of two pieces of bamboo, 1/32″ square and long enough to keep the propeller from touching the ground, ambroided to the motor stick one on each side and slanting downward at an angle of sixty degrees from the horizontal. Another short piece of bamboo should be placed across these members, so that the whole structure looks like the capital letter 'A.' Now place two small L-shaped pieces of piano wire at the bottom of the uprights, ambroiding them so that two sections will project to form axles. Slip wheels over these axles, and then place a drop of ambroid on the ends of the axles to keep the wheels from coming off. Don't glue the wheels on. Naturally they will not turn if you do! (This method of constructing a landing-gear was diagrammed in Chapter VIII, 'Baby R.O.G.')

CHAPTER XI

THE OUTDOOR TWIN PUSHER

THE twin pusher described below is identical with the one used by Jack Loughner in winning the Mulvihill Contest at Philadelphia in 1926 and the National Playground Miniature Airplane Senior Outdoor Contest at Memphis in 1927. The secret of Loughner's success is in his workmanship and the extreme lightness in construction.

Many boys substitute white pine for the balsa parts, but in doing so they cut down their duration because of the increase in weight. Balsa is so much lighter than any other wood, and so strong for its weight that model-builders cannot afford to be without it.

The wing used in the twin pusher is known as a built-up or double surface wing. Airplanes in the early days of aviation had wings designed to imitate the wings of birds. They were built up with a supporting structure of ribs and spars and covered, forming a single-cambered or curved surface. Experiments soon showed that the wing became more effective when both sides were covered, enclosing the ribs and spars.

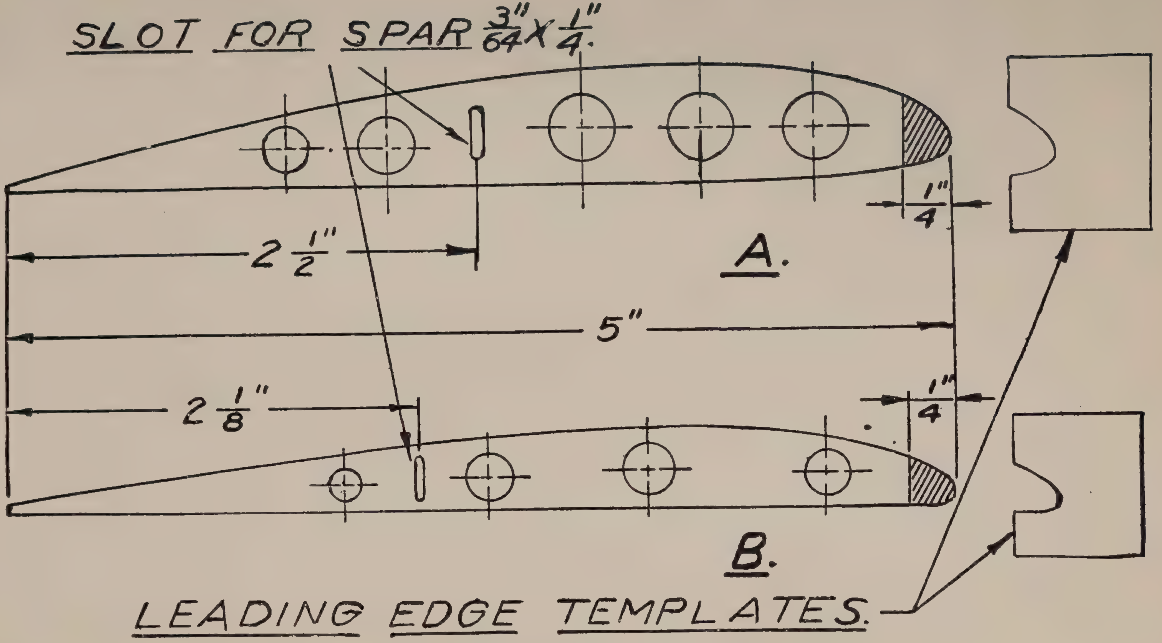
The two sections shown in the drawing (No. 21) are both very efficient for model-building. The section marked A is the Clark Y, and is probably used on more ships to-day than any other section. Some of the ships using this section are the Curtiss Hawk, the Spirit of

St. Louis, the Stinson Biplane, the Hess Bluebird, the Buhl Airsedan, and a multitude of others. All that needs to be said about the lower section B is that it is the section used by Jack Loughner in winning the 1926 Mulvihill Contest. The beginner would do well to select the Clark Y, section A, to start with, as the thicker section permits the use of a larger spar through the center giving the whole wing more strength, which prevents it from warping while under construction.

The ribs must be made as carefully as possible, being sure you get the curves accurate, as the efficiency of the wing depends largely on this. An easy way to do this is to make a rib from sheet brass, and by using this as a pattern the ribs may be cut out around it. Such a brass rib is called a template. The drawings of the wing sections were carefully made and can be transferred to the brass either by tracing or by pasting the drawing on the metal, and can then be cut out. This is done with tin snips and the template is then smoothed with a file to remove all the rough edges.

The slot for the spar may vary in size. The drawing calls for 3/64″ × 1/4″. This is just right for the endurance plane, but the beginner should have a larger spar, especially when using the Clark Y. A slot 1/8″ × 5/16″ for the Clark Y and 1/8″ × 1/4″ for section B is recommended. Do not attempt to cut this slot in your template, but drill a small hole at each end of the slot, using a drill with a diameter equal to the width of the slot. If you can't get a drill, you can locate the ends of the slot by driving a Victrola needle through the brass template.

WING SECTIONS.



NO. 21. HERE'S YOUR WING SECTION

Most beginners use the thicker one, marked A. Make a tracing, paste it on brass, and cut out a brass template, or pattern. Mark the center of each hole and the ends of the slot by punching a phonograph needle through the brass. Then you can construct each of the ribs for your wing exactly the same.

This permits you to mark the ribs through these holes. You must get this slot exactly the same in each rib or they will not line up and your plane will be useless for flying. For this reason you must have some accurate method of transferring the slot from the template to the ribs.

The round holes are to lighten he ribs and, although not essential, help to cut down weight considerably. The best way to transfer these is to use the Victrola needle method of making a hole at the exact center of the circle. You'll notice that the holes are of different sizes. The three larger holes, section A, should have a 3/8″ diameter and the other two should have diameters of 5/16″ and 1/4″, respectively. There are only four holes in section B, as it is a thinner section. The largest of these is 5/16″ in diameter, the next two have diameters of 1/4″, and the smallest one 3/16″.

This completes the template of the wing with the exception of the leading edge. You will notice how this is shaded in the drawing to 1/4″ back. This part of the wing is formed by a solid balsa beam shaped to the leading edge curve. The ribs are cut off and butt-jointed to this beam. Notice the photograph of the wing tip assembly.

The leading edge template may be made by pasting the drawing on a small square piece of sheet brass and with a file finishing it to the line. A six-inch round needle file is very good for filing the curve. When this fits the leading edge of the rib template, you may cut off the shaded section as shown. You should take special care in cutting this to get it perfectly square. This completes the templates and you are now ready to cut out the ribs.

Beginners can purchase finished sets of balsá ribs for these planes from the Michigan Model Airplane Supply Company, 4768 Grand River Avenue, Detroit, Michigan. These ribs are all cut in dies, and for the beginner are of untold help. The stock from which the ribs are made should be about 1/16″ in thickness and uniform throughout. The template is laid flat on this and the rib is cut out around it with a razor blade or sharp knife. Without removing the template, the slot and lightening holes should be marked with a sharp lead pencil or Victrola needle through the center holes. There are thirteen of these ribs, and every one must be identical.

Now, with a razor blade or the point of your knife, cut out the slot. If you grind a half-circle in the cutting edge of the razor blade 1/16″ from the end, it will make a very good tool for cutting out the slots.

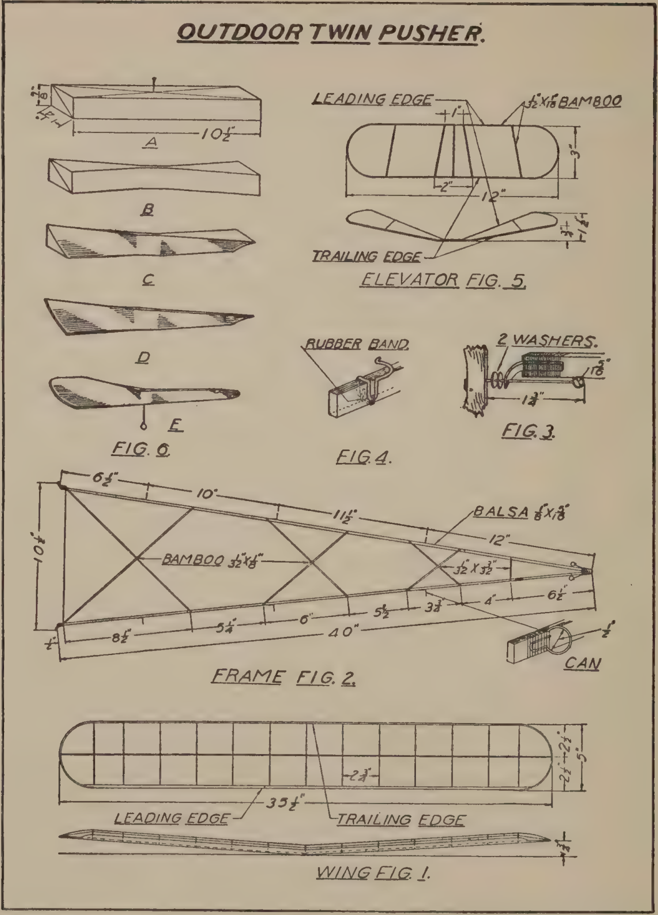
The lightening holes can be drawn with a compass and then cut out with the razor blade, or, if you have wood bits, the holes can be cut out by turning these into the wood by hand until the knife edge at the bottom enters the wood, and then removing it and repeating in the same manner from the other side. This will allow the center section to drop out, and if the bit is sharp should leave a smooth clean hole.

The two leading edge beams are made next. These are made of balsa, and their shape is clearly shown in the drawing. The curve can be roughed out either with a small plane or jackknife. You should frequently check this with the brass leading edge template. When almost to size, the final shape may be given to them by using the leading edge template as a scraper. This is done by drawing the scraper toward you and at the same time inclining it toward the beam. You must be careful not to let the template twist in your hand, as this will gouge and spoil the beam.

Now you are ready to make the tips. The drawing (No. 22) shows round tips on the wing, but you may change these to any shape you wish. The round or elliptical ones are more efficient, but some boys prefer the looks of the positive rake type. Many different shapes can be copied from planes shown in aviation magazines. As the tips are rather hard to cover, many boys let the end rib act as the tip on the first wing. This would give you a square tip.

If you decide on other than the square type, the tip should be made of bamboo. Bamboo, as you know, is very pliable when hot, and can be bent to any desired shape which it will retain when cool. This can be done over a candle or alcohol lamp. In preparing bamboo for bending, it should be carefully split, not cut, as near to the required size as possible. When this is done you should finish the piece by splitting small slivers off the side and then sandpapering until the piece is uniform in thickness the entire length. This is extremely important if you wish to get even bends in the bamboo parts. Variations in size will always make sharp, unsightly bends instead of smooth, graceful ones.

The bamboo for the wing tips must be 1/16″ square and 15″ long. An easy way for you to check the shape


OUTDOOR TWIN PUSHER.
10½"
A
B
C
D
E
FIG. 6.
LEADING EDGE
1"
1/32" X 1/16" BAMBOO
3"
2"
12"
1½"
TRAILING EDGE
ELEVATOR FIG. 5.
RUBBER BAND
FIG. 4.
2 WASHERS.
1 3/4"
FIG. 3.
6½"
10"
11½"
12"
BALSA
10½"
BAMBOO
5¼"
6"
5½"
3¾"
4"
6½"
8½"
40"
½"
CAN
FRAME FIG. 2.
2¾"
2½"
5"
35½"
LEADING EDGE
TRAILING EDGE
WING FIG. 1.

NO. 22

of the tip while bending is by laying it on a full-sized drawing of the curve as you form it. Be sure to bend the ends so that they will gently curve into the leading and trailing edges, forming continuous lines with the outside edges of these. In the case of the leading edge, it must overlap at least a half inch. The leading edge spar is grooved to receive it. The trailing edge should form a half-lap joint with the tip and, when cutting the tip to size, after bending, you should allow stock for these joints. The tip is now split to form two identical pieces and after trimming and sandpapering are ready to assemble.

The trailing edge is made of bamboo 1/64″ × 3/64″ which extends from one wing tip to the other with the thin side parallel to the ribs.

You are now ready to assemble the wing. This is done one half at a time. The first step in assembling is to taper the end of the leading edge to fit the wing tips. (See the drawing, Figure 1; also, the photograph of wing tip assembly.) Notice that this is all done on the top so as to leave the bottom of the wing flat. While doing this, groove your leading edge to receive the tip. Now you can taper the end of the center spar to the thickness of the tip in the same manner. (See the photograph.)

You should make the positions of the ribs on the center spar and leading edge 2 3/4″ apart. Next, shallow grooves are cut into the leading edge at these points the width of the ribs and about 1/64″ deep. Now you are ready to slide the ribs onto the center spar, and, when these are all checked up for squareness, they may be ambroided in place. Ambroid should be used sparingly but effectively. An easy way to check the trueness of the wing is to lay it on a piece of plate glass or other LEVEL surface, making sure that every rib touches along the entire bottom. If the ends of any of the ribs have a tendency to stick up higher than the others, the slot must be enlarged to permit it to revolve parallel to the rest. The sides of the ribs must also form a ninety-degree angle with the center beam. Next you can ambroid the leading edge beam in place, making sure that the end of each rib is fitted into its proper groove and forms a continuous curve with the leading edge. The tips are then glued in place, a couple of turns of silk thread around the joint of the leading edge and the bamboo trailing edge will help to make it stronger. The trailing edge may be made up of pieces of bamboo half-lapped and bound with silk and securely ambroided.

You are now ready to assemble the two halves of the wing. If you place a block one inch square by six inches long under each tip in such a manner that the beams will overlap about an eighth of an inch, you will have the correct dihedral angle. This will enable you with a razor blade to cut down through both of them at the same time. In this manner you will get a perfect-fitting butt joint for both center and leading edge beams. These beams may also be half-lapped or mortised if you prefer a stronger joint.

Now slip the center rib into place and ambroid both the joints. The wing should be left on the block for an hour or so until the ambroid is thoroughly dry. The trailing edge is then finished, completing the frame of the wing.

Your next job is to cover the wing with Japanese imperial tissue. Banana oil is used to fasten the paper to the wing. The top of the wing should be covered first, then the bottom. Paint the center rib with banana oil and stretch the edge of the paper across the top from trailing edge to the leading edge. The paper should overlap the trailing edge about 1/16″, which is later turned under. The rest of the paper should extend past the leading edge far enough to fold under and completely cover the bottom of the wing. As soon as the center rib is dry, the frame is painted up to and including the next rib and this section covered. Be sure you draw your paper tight, lengthwise rather than crosswise, in order to preserve the correct shape of your section. Proceeding in this manner, section by section, you may cover the entire wing.

Remember that you always work from the center to the tip, and that, if you stretch and hold your paper in place, wrinkles can be prevented. After finishing the top of the wing, the overlapping paper is folded under and the bottom of the wing is covered in the same way as you did the top.

After you have completely covered the wing, it should be doped. A good dope may be made by mixing five parts of acetone to one of banana oil. Two coats of this will glaze and shrink your paper in place. Too much dope will shrink it till it warps the wing all out of shape.

The A-shaped frame is made by fastening two balsa beams together to form a large 'V,' using cross-bracing to support and strengthen the whole. For a light model these pieces may be 1/8″ × 1/4″ and rounded well at the corners. A beginner should use beams 1/8″ × 5/16″ until he is familiar with launching his model, as the lighter frame will crack up very easily. The ends where the beams are joined should be cut at an angle to ensure a good joint and ambroided in place.

The cross-bracing is the strongest bracing yet developed, and not only combines lightness with strength, but also stiffens the frame to withstand almost double the strain ordinary bracing would allow. The braces are made entirely of bamboo. Notice that the drawing shows heavier bamboo used in the widest part of the frame, as this is where the most strain is exerted. The first two Xs are made with 1/32″ × 1/8″ bamboo, the last two from 1/32″ × 3/32″ pieces of bamboo. These are inserted in slits formed in the frame and should be long enough to protrude through. These ends are cut off after the braces have all been adjusted and ambroided in place. The slits can be formed by laying the beam flat on the bench and gradually working the point of your knife through. The center of the X should be bound with silk thread and ambroided. These braces will straighten out the frame and hold it true, and in assembling you should take care to see that the frame is straight before the ambroid dries.

The bearings are made from one-sixteenth-inch nails or brads forged flat, and are drilled to allow the propeller shaft to pass through them. These are bent as shown in the drawing. The part lying along the beam (see Figure 3) should be flattened out considerably more than the rest to ensure a good fit on the beam. The bearings should not extend out from the frame more than one quarter of an inch. These are first ambroided and then bound with silk thread.

The six cans or hooks along the side of the frames are very important, as they prevent the frame from bending under the strain of the rubber and breaking. The principle of these is the same as that employed on a flexible steel fishing rod, where guides or eyelets are used. These cans are made from Number 10 music wire, and their shape is clearly shown in the drawing.

You should leave the cans open at the top to allow the rubber to be slipped into place when it is wound. The correct position for these is shown in the drawing.

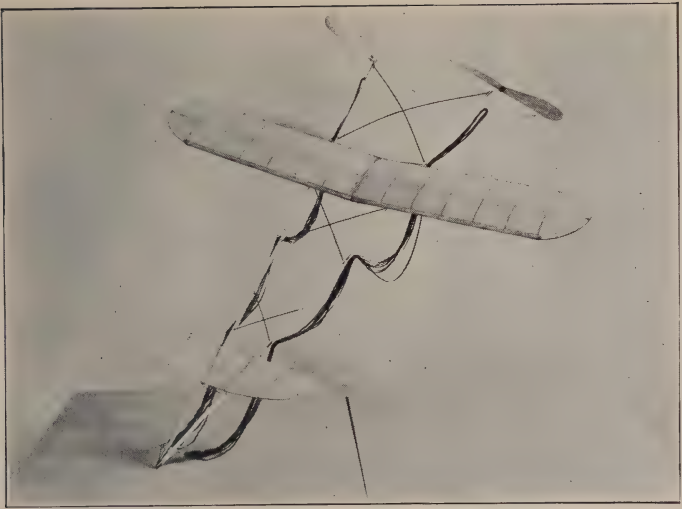
The front hook is made of Number 15 music wire, and is bent around the front of the frame to form a yoke with two eyes on each side. These eyes or hooks do not need to be large, as 'S' hooks are used to fasten the rubber to them. The front hook should be bound with silk and then ambroided.

In finishing the frame you can materially strengthen it by stretching a silk thread across the frame a half inch from each bearing where the bamboo braces enter the frame. A coat of banana oil will add considerable strength to the frame.

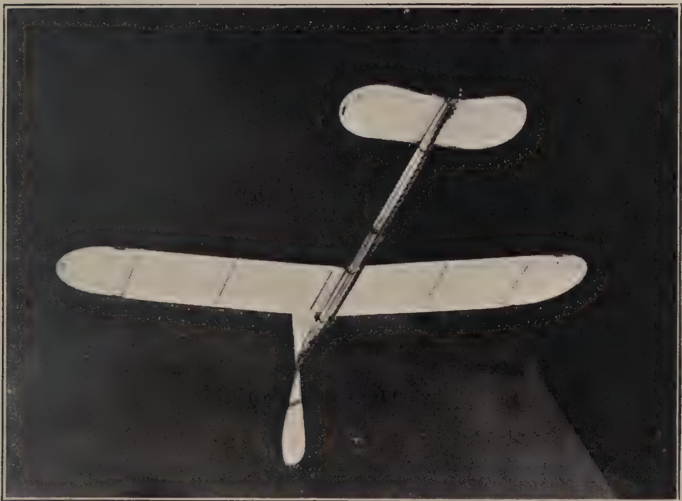
In making the elevator, extreme care must be taken to get both halves identical. If one side has more incidence than the other, the plane will not fly properly. Notice that the trailing edge forms a flat 'V' and the leading edge forms a sharper 'V,' so that the outer edge of the leading edge is three quarters of an inch higher than that of the trailing edge.

The first step in making the elevator is to split the bamboo parts to size. You should form the tips in the same way used in making the wing tips. The frame and ribs are all made from 1/32″ × 1/8″ flat bamboo. The halves of the trailing edge and the tips should be made from one piece of bamboo an eighth of an inch square, and then this is split to form two pieces for the two halves. Using this method the angle of incidence may be given the frame by bending this piece at the point where the trailing edge curves into the tip so that the tip will extend upward just high enough to fit the end of the leading edge. By bending and carefully fitting, a very neat job may be made. The leading edge is formed from one piece of bamboo bent in the center forming a 'V,' with the outer ends 1 1/2 inches above the center. The 'V' formed by both the leading edge and trailing edges does not come to a sharp point in the center, but is bent flat as shown in the drawing. After the frame is bent and assembled, the five ribs are ambroided in place as shown.

The last job to be done is the making of the propellers. There are two of these; one right-hand and one left-hand, as they must turn in opposite directions to one another to keep an even flight. The balsa blocks for both propellers should be squared up on all sides and matched. When finished they should be 7/8″ × 1 1/4″ × 10 1/2″. These dimensions may be altered to a slight extent without much change in the performance of the model. Remember that the diagonals on each end are opposite



THE ASSEMBLED OUTDOOR TWIN PUSHER READY TO FLY



THE INDOOR PUSHER IN THE AIR

to each other and the propellers are right-hand and left-hand, turning in opposite directions. The propellers are carved in the same manner as described in Chapter V.

The small 1/4″ washers are made from sheet brass or can be bought in department stores, where spangles for ladies' dresses are sold. These are used to cut down friction between the propeller and the bearing.

The plane derives its power from eight strands of 1/8″ flat rubber. This rubber should have about two inches of slack when laid unwound in the cans. The pilot should always have a good reliable mechanic to work with him in winding the plane, and whenever possible the same one, as thus they will learn to work together better and prevent mishaps. When winding, 'S' hooks should be used to attach the rubber to the winder. With the mechanic holding the propellers at the hubs in such a manner as to stop them from turning, and also to take all the strain off the frame, the pilot backs away about four or five feet from the model, in order to stretch the rubber before winding, as more turns can be given when it is stretched. The winder should be turned so that the rubber is wound in the direction the propellers should turn in flight. Directions for making the winder will be found in Chapter VI.

The first flight should not be attempted until the plane has been adjusted to glide evenly, and then a trial flight made with only about five hundred turns on the rubber to test the adjustments. When the plane is properly adjusted it may be completely wound about twelve hundred turns and carefully launched.

In launching your plane, grasp the two propellers as shown in the photograph, gradually lift the nose into the air until it is tilted slightly upward. By releasing the plane with a slight push, you will be able to get off without mishap. Never launch your plane with the wind, but always against it.

CHAPTER XII

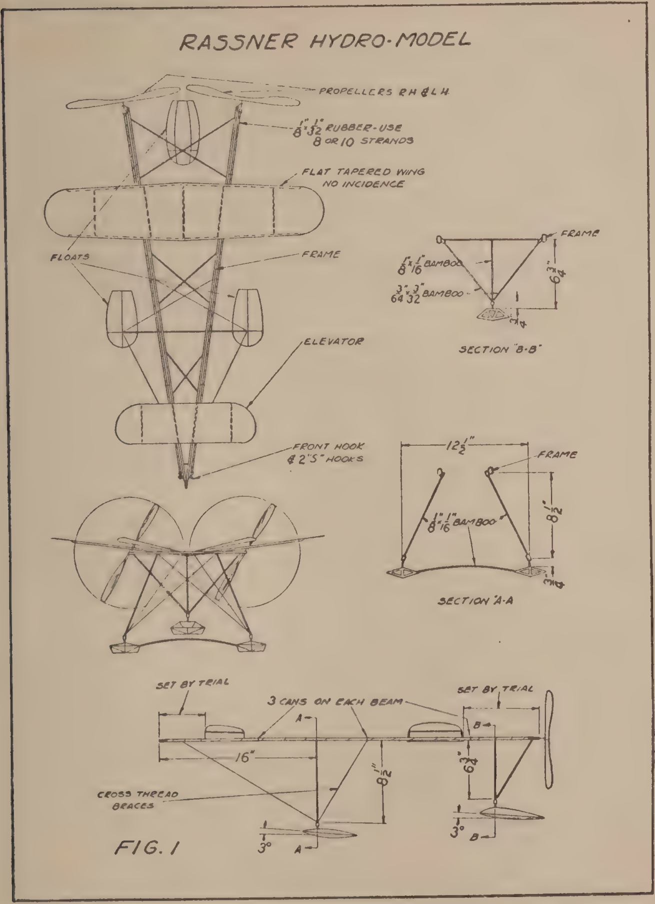
VIRGIL RASSNER HYDROAIRPLANE

THE hydroairplane is a champion, having established the world's record of 2 minutes, 52 seconds for rubber-driven model hydros in 1921. It was designed and flown by Bertram Pond, one of the foremost model-builders in the country. Mr. Pond established the world's indoor record of 170 seconds, and held it for five years, till 1926, as well as having twice won third place in the Mulvihill Contest and sixth place once. Mr. Pond has given us the exact drawing of his record model with newly designed set of floats. With this ship and the new floats, Virgil Rassner, one of Mr. Pond's students, won the junior hydro contest in the 1927 National Playground and Recreation Contest at Memphis.

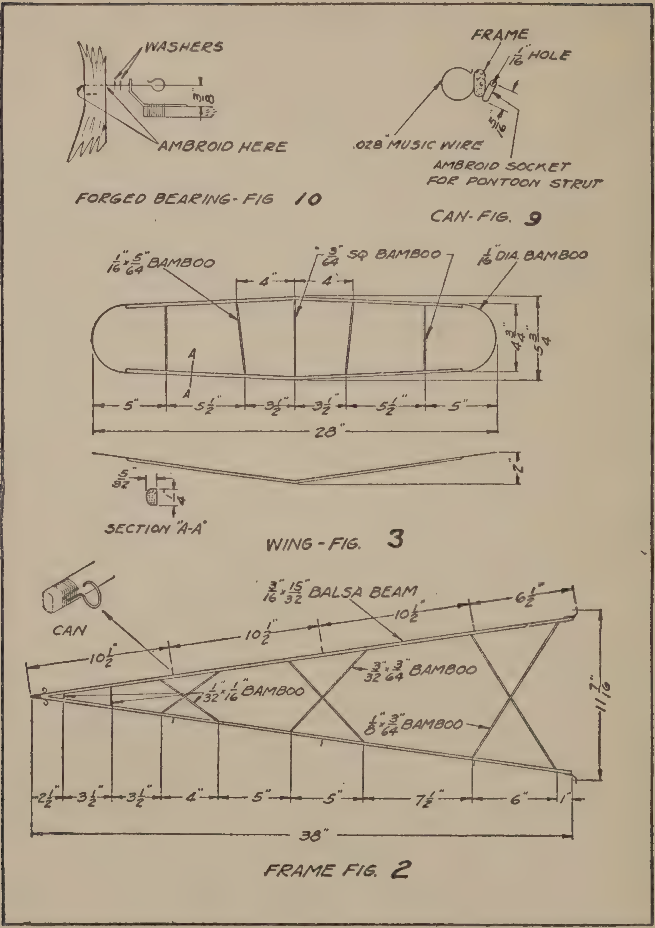
Before beginning to construct your model, study the drawings (Nos. 23 and 24) carefully. Note especially how the plane is assembled. This is shown in Figure 1, giving top, front, and side views of the assembled model. Compare these with the photographs of the model so that the position and shape of each part are fixed clearly in your mind. The two sectional drawings of the pontoons are shown to help you to see just how the floats are assembled. Section AA pictures just exactly how the cross-section of the front floats would look if they were cut through on the line marked *AA* and section BB shows the same view of the rear float along the line *BB*.

We will begin by constructing the frame (Figure 2). This is the A type, with cross-bracing similar to the one used on the twin pusher. The two beams are made extra heavy to take the strains that an R.O.W. ('rise off the water') plane is subject to. When finished the beams should be 3/16″ × 15/32″ × 38″, rounded at the corners, well sandpapered and exactly straight. When these pieces are finished, they should be laid together, forming a 'V' with the rear ends 11 7/16″ apart. While in this position the front ends should be beveled to make a neat joint and ambroided. The yoke (front hook, Figure 8) can be fitted and ambroided in place to hold the pieces while drying. A few turns of silk thread will make the whole much stronger. While the front end is setting, you can make the bamboo braces for the frame. Notice that the longer ones are made larger better to prevent buckling when under the strain of the rubber. By the time you have these split to size, you can lay out the frame, beginning at the front brace, which is two and a half inches from the front. These braces extend through the frame, and when in place are ambroided on both sides. The frame should be pierced with the point of your knife while laid flat on the bench. The end of the bamboo brace is sharpened to a point and then pressed through the slit formed by the knife point. When the braces are all in place, the frame should be carefully checked to see if it is exactly straight, and then the braces ambroided in position.

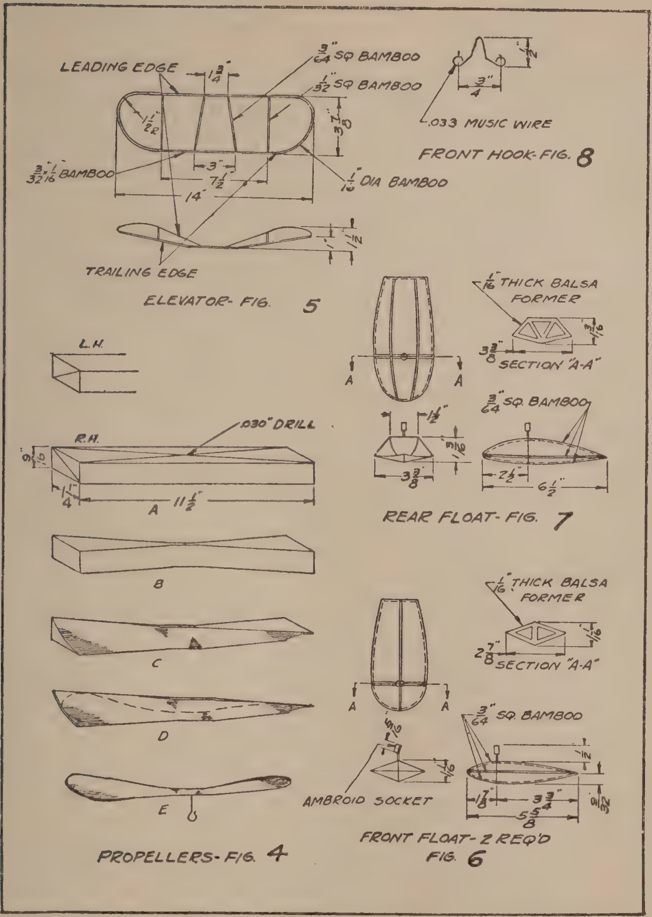
While the braces are drying, the metal fittings may be made. Begin with the six cans. These prevent the frame


RASSNER HYDRO-MODEL
PROPELLERS RH & LH
1/8" × 1/32" RUBBER - USE 8 OR 10 STRANDS
FLAT TAPERED WING NO INCIDENCE
FLOATS
FRAME
ELEVATOR
FRONT HOOK & 2 "S" HOOKS
FRAME
1/8" × 1/16" BAMBOO
3/64" × 3/32" BAMBOO
6 3/4"
3/4"
SECTION "B-B"
12 1/2"
FRAME
1/8" × 1/16" BAMBOO
8 1/2"
3/4"
SECTION "A-A"
SET BY TRIAL
3 CANS ON EACH BEAM
SET BY TRIAL
A
B
16"
8 1/2"
6 3/4"
CROSS THREAD BRACES
3°
A
3°
B
FIG. 1

NO. 23



NO. 24. DETAIL DRAWINGS OF



RASSNER HYDROAIRPLANE

from bending when under the strain of the rubber in the same manner as eyelets on a fishing rod prevent it from bending. The shape of these is clearly shown by Figure 2 in the small drawing in the upper left-hand corner and the end view in Figure 9. There are three of these on both beams made from .028″ music wire; the spacing for them is given at the top of the drawing. The loops should be a half inch in diameter so that the rubber will have plenty of room in which to turn. Notice how the wire is bent at right angles to the loop in order to fit parallel to the beam, where it is ambroided and bound with a few turns of silk thread in place.

Figure 10 shows the forged bearings, which are made from a small nail drilled with a .035″ drill to fit the propeller shafts. When in place on the shaft, this hole should be just three eighths of an inch from the beam (see drawing, Figure 10). Thrust bearings already drilled and bent are furnished in the kit.

We are now ready to construct the wing. This is a single surface flat wing, in many ways resembling those you made for your indoor models. The four spars are made from balsa strips, finished to the shape as shown in section AA and are 11 5/8″ long. The position of the five ribs should be next marked off on them and we are ready to begin assembling.

If you make a large drawing the size of the wing, it will help you to get the correct angle to your spars as well as give you a form to which to bend your wing tips. Two spars, end to end with the curved side down, form the leading and trailing edges. The ends of these spars are one inch closer together than they are at the center. The dihedral angle may be given the wing by placing a block 1 11/16″ high under the outer ends of the spar while the ambroided butt joints are drying at the center. The wing tips should be bent from one piece of bamboo 1/16″ × 1/8″ × 9″ to fit the form of your drawing. When you have them bent correctly, they should be split and the corners well rounded and cut to length. Be sure you leave enough on the ends of the tips to allow a half inch for lapping when joined to the spars.

The spars can now be grooved so that the tips will set flush with the outside of the spar to form a continuous curve. When this is done, ambroid the tips in place, being careful to keep them parallel to the spars so that when the paper is put on it will lie flat along the entire length of the wing. Next the grooves for the ribs should be cut 1/16″ deep, and the ribs ambroided in place just even with the surface of the spars. The wing is covered with Japanese imperial tissue; beginning with the center rib, the frame should be painted with banana oil and the paper laid in place. Wrinkles can be prevented if the paper is perfectly flat when placed in position. Should your paper contain wrinkles, it must be ironed out and allowed to cool to the room temperature before using, to prevent future warping. As soon as the paper dries, another section may be covered, always working from the center toward the tips until the wing is covered. The edges of the paper can be trimmed with a sharp razor blade or by carefully rubbing with fine sandpaper. The rough edges can be fastened down by painting with banana oil. The entire surface of the wing is later painted or doped with a solution of five parts of acetone to one of banana oil. This is followed when dry by four separate coats of banana oil. This is to shrink and waterproof the wing. Most hydros get wet all over at one time or another, and must be made waterproof to prevent them from being spoiled.

The next job is the carving of your propellers. There are two of these, one right-hand and one left-hand, as they turn in opposite directions to one another and thus neutralize the torque. These are carved from blocks, 9/16″ × 1 1/4″ × 1 1/2″. Like the rest of the plane, the propellers must be given five coats of banana oil to waterproof them.

Figure 5 shows two views of the elevator. This should be carefully studied before construction is started. The entire frame is made of bamboo bent to the shape as shown in the drawing. This is constructed essentially the same as the one used on the outdoor pusher.

The success of the entire plane as a hydro depends on the floats. These must not only be properly constructed, but must be assembled correctly or the plane will not rise from the water. In designing pontoons we have to make them large enough so that when they are totally immersed the weight of the water displaced will be three times the weight of the whole plane. This allows the floats to sit well up on the water when supporting the plane. Notice that Figure 1 shows the floats set at an angle of three degrees. This may vary from two to five degrees without much change in efficiency in the floats.

The 'V' bottom floats are much better than the flat type so common on models, as they prevent the plane from turning on its course when taking off. This type also rises from the water much more rapidly, as it cuts down suction on the bottom of the float, and in landing they take up the shock of landing, as the 'V' cuts into the water and breaks the force of the blow.

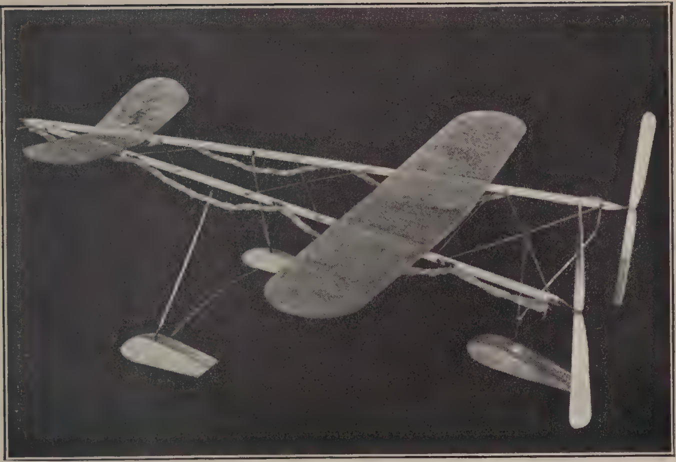
The floats are formed of 3/64″ bamboo bent around the balsa former shown in the drawings. This former is cut from 1/16″ flat balsa to the shapes as shown in Figures 6 and 7. Notice the triangular lightening holes to cut down weight. The corners of these formers should be painted with ambroid to strengthen and prevent chipping.

The two front floats (Figure 6) should be made first. If you will make a full-sized drawing of the top view, it will help you to bend to the correct shape the V-shaped bamboo pieces which form the sides. These pieces can all be made from 3/64″ × 1/8″ × 15″ bamboo, and the parts for both pontoons split from one piece. When the side pieces are completed, they can be ambroided to the balsa former as shown in the drawing. The top and bottom pieces can now be bent and fitted in place, completing the frame of the float. When finished, the nose should be rather flat at the extreme point rather than sharp, to prevent it from nosing under in rough water. Before covering, the bamboo strut which supports the ambroid socket must be ambroided into place at the exact center of the pontoon and to the balsa former. The floats are covered with tissue given five coats of banana oil to waterproof them. Care must be taken not to puncture the floats in covering and to check them to see that there are no leaks. The rear float is made exactly in the same manner as the front floats and differs only in size and by the addition of two ribs on top instead of one.

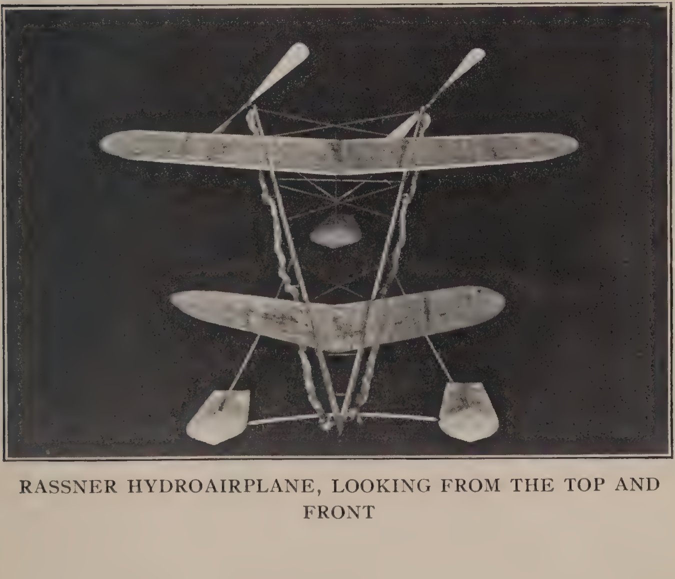
If the model could not be taken apart when not in use, it would be very unhandy to carry about. For this reason it is equipped with small sockets which allow the supporting struts to be slipped on or off at will. These sockets are formed by rolling tissue about a 1/16″ nail, covering the whole with several coats of ambroid, winding the tube thus formed with a few turns of thread to increase the strength. When these are dry, they can be slipped off the nail and ambroided to the pontoons as shown in the drawing. Similar sockets are ambroided to the beams and to the cross-bracing where the supporting struts fasten to the frame.

Study the assembly drawing of the plane and the shape of the struts; if you glue the sockets to the frame at an angle as shown in Figure 9, the struts will have to be bent only at the point where they enter the pontoons. These struts are made of 1/16″ × 1/8″ bamboo and are rounded at both ends to fit into the sockets. The front pontoons have two of these running to each side of the frame. The floats are held apart and the whole strengthened by a curved brace joining the two. This brace is ambroided to the edges in line with the balsa formers.

Additional bracing is given to the floats and undercarriage by two threads running from the sockets to the second cross-brace on the frame, six inches from the nose.



SIDE VIEW OF RASSNER HYDROAIRPLANE



RASSNER HYDROAIRPLANE, LOOKING FROM THE TOP AND FRONT

Two other threads cross each other to the opposite side of the frame.

The rear float is supported by three struts. The center one fits into the socket at the center of the last cross-brace at the rear end of the frame. The two supporting braces extend, from this center strut, just above the socket, where they are joined by ambroiding to one inch from the ends of the beams, where the ends of the last cross-braces enter the frames, where they fit the sockets ambroided here to receive them. By using this method of attachment, the entire undercarriage and pontoons may be quickly put together or taken apart for packing in an airplane box.

The motive power for this ship is derived from two ten-strand 1/8″–30 rubber motors. The wings and elevator are held in place by rubber bands which extend under the frame and over the surfaces, thus allowing them to be shifted to get the right setting.

The ship should be glided before attempting to fly it. As the pontoons are easily punctured, this should be done in soft grass or under similar circumstances where the floats will receive protection. If the plane attempts to climb or nose up in the glide, the wing should be set back; if it drives, it should be set forward.

In launching, the plane should be wound with a double winder, giving it about six hundred turns to begin with, using 'S' hooks to connect the motor to the yoke when transferring it from the winder. When wound, the plane is set on the water and held by the propellers. When all is ready, these should be released at the same instant, and if the plane is properly constructed and adjusted it will skim lightly over the water for a short distance; then, gathering speed, it will slowly rise from the water and the chase is on. The hydroplane, like all other ships, should be launched against the wind and never with it, or it is almost sure to crack up before getting off.

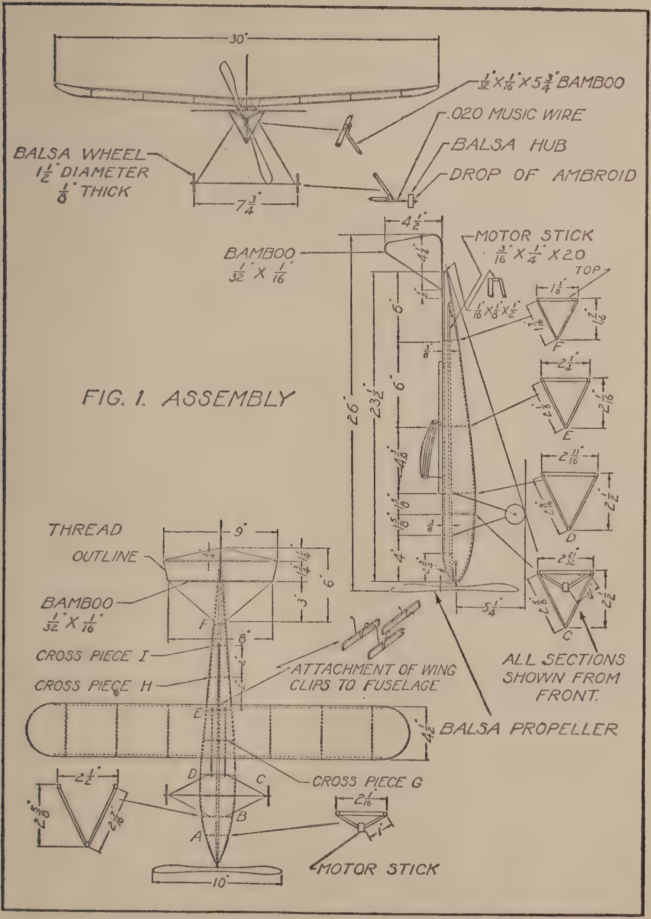
CHAPTER XIII

THE INDOOR COMMERCIAL MODEL

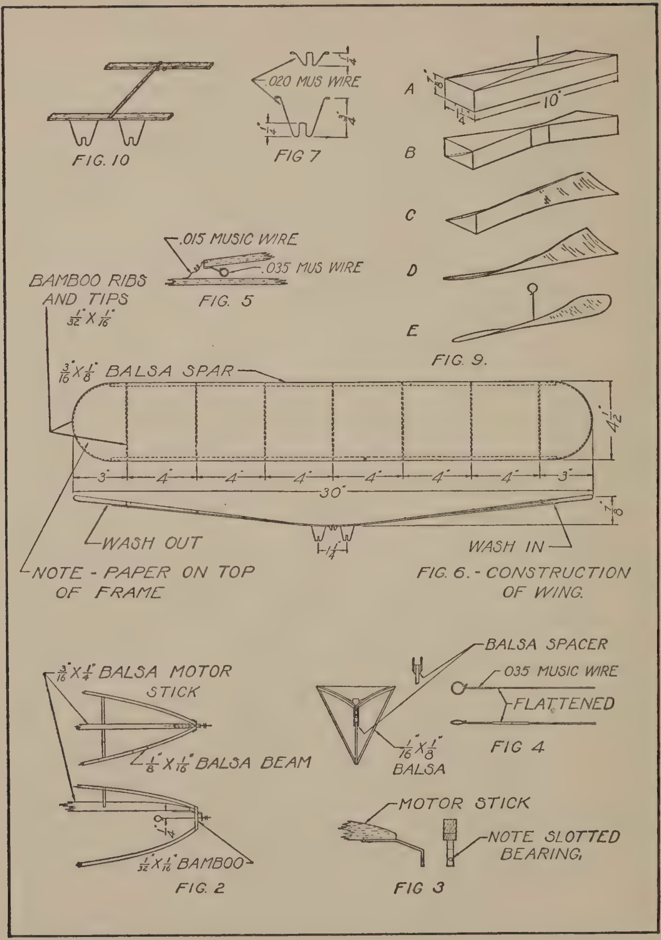
A COMMERCIAL model has a built-up fuselage and is designed primarily to fly. Although not necessarily a copy of any real ship, it should have the general appearance of the large airplane. A scale model differs from the commercial in that it is an exact replica of a large airplane scaled down, and seldom if ever flies. This is readily understood when we realize that the weight of the engine in an airplane brings the center of gravity well up in front, and to balance the airplane the wings have to be set also well up in front on the fuselage. This is all figured out by the designer before the plane is built, and whenever any of the parts of the plane are shifted, such as the engine or fuel tanks, a corresponding change must be made in the control surfaces. The scale model-builder usually resorts to a dummy engine, which is much lighter than a real engine scaled down would be. Of course, this results in throwing the whole model out of balance, and either the wings must be moved back (which would take it out of the scale model class into that of the commercial) or enough weight added under the cowl to balance the ship. This makes it so heavy that flight is almost impossible, owing to the lack of lift at the slow speeds at which models fly.

The indoor commercial model described here has several new features that make this model superior to the average plane. Probably the most important of these is the method used to support the motor stick. This stick extends through the center of the fuselage and carries the strain of the rubber motor. It is shown very clearly in the drawings (Nos. 25 and 26) and photographs. Notice that it is supported in only three places, two in the front, and one in the rear. Sections A and C show the two front connections and Figure 5 shows the rear spring support. Whenever a rubber motor is wound ready for flying, there is a considerable force tending to twist the motor stick in the opposite direction from that at which the propeller turns. This force, known as torque, is sufficient in a light model to twist the whole fuselage enough to prevent flight. In order to prevent this, most model-builders design their fuselage structure sufficiently heavy to withstand the strain, thus adding a great deal of unnecessary weight. As most of the twist will be absorbed by two thirds of the stick, if free to turn, the motor stick in this model is supported at the rear end by the spring support as shown in Figure 5. The spring allows the stick to twist without affecting the fuselage, and anchors the end in place sufficiently to prevent the stick from moving back and forth or breaking loose.

The method used to attach the wing, although new in commercial planes, is familiar to flying-stick model-builders. It allows the wing to be quickly adjusted and when not in use to be packed away in your airplane box. The three supporting beams must be exactly parallel or the wing clips will not fit over them at different positions. (See the small drawing showing these above the wing in the top view of the assembled drawings in Figure 1.)



NO. 25. ASSEMBLY DRAWING OF INDOOR COMMERCIAL PLANE



NO. 26. DETAIL DRAWINGS OF INDOOR COMMERCIAL MODEL

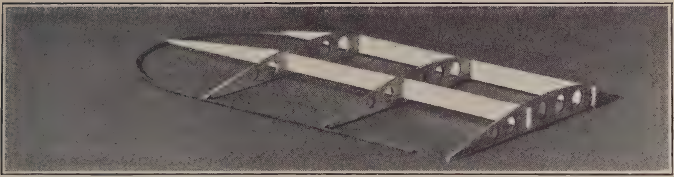
Before beginning to construct the model, study the drawings carefully, making sure you understand exactly where each part belongs and how it is constructed. This will prevent you from spoiling part of your material as well as save you much time in constructing your model.

Let us begin by building the fuselage. This is triangular in shape, the strongest cross-section that could possibly be used, and is perfectly stream-lined the entire length. Figure 1 shows the construction of the fuselage with the full-sized cross-section drawings at one side. Ambroid together the ends of 3/32″ × 1/8″ × 24″ balsa beams in the shape to form the top of the fuselage. This will form the rear end of the fuselage, and 6″ from this end glue a 1/16″ × 1/8″ × 1 1/4″ cross-piece (section F). The section drawings show the distance across the fuselage including the thickness of the fuselage beams. Section F is 1 3/8″ across, so that the cross-piece will equal 1 3/8″ minus twice the thickness of the beam, or 3/16″. Therefore, the cross-piece of section F equals 1 3/8″ minus 3/16″ or 1 3/16″. Likewise section E, which is 2 1/4″ across, has a cross-piece of 2 1/16″. Six inches farther the 2 1/16″ cross-piece is placed between them (section E), and 4 1/2″ farther the 2 1/2″ cross-piece is inserted. (See section D.) When the glue is thoroughly dry, the two spread projecting ends may be steamed by holding them over the spout of a tea-kettle. They should be moved back and forth so that they will be steamed evenly from the last cross-brace to the ends. When these are thoroughly steamed, the ends may be bent together until they touch, thus forming the nose, and can be held in place by thread binding. Now, by laying the whole upside down, flat on the table, and placing a heavy weight on top of it, the nose may be bent up and held in place with a 5/8″ block under it in order to hold the curve until it dries.

While in this position the two other cross-pieces, one 1 7/8″ long and the other 2 15/32″ long, should be set in their proper places. The 1 7/8″ piece is 2 3/4″ from the nose, and the 1 15/32″ piece is four inches from the same point. These pieces should not be ambroided in place until the beams are dry, but are placed in position to give them the proper curve while drying. As soon as they are thoroughly dry, all the joints should be ambroided and the thread on the nose removed.

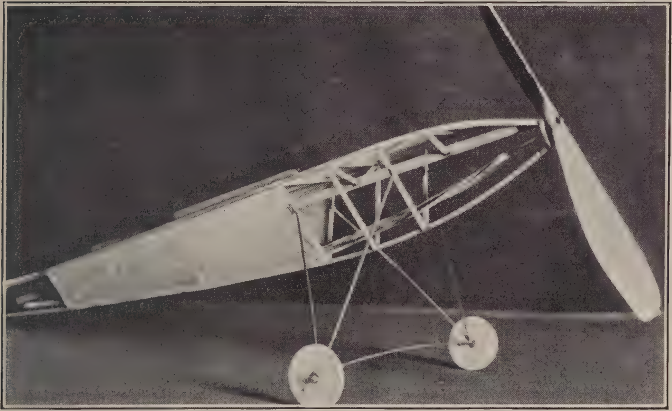
The cross-piece *G* is placed halfway between sections D and E, and is approximately 1 3/8″ long. All the cross-pieces should be cut to fit between the fuselage beams rather than the sizes given, which may vary on different models because of the amount of curvature. The cross-pieces *H* and *I* are ambroided between *E* and *F*, 2″ apart, *H* being 2″ from section E (see the drawing of top view, Figure 1). *H* is 1 3/4″ and *I* is 1 1/2″ long. This completes the top frame of the fuselage.

Now for the motor stick. This must be made from a piece of firm straight-grained balsa. When finished, it should be 3/16″ × 1/4″ × 20″, well sand-papered and perfectly straight. The front end may be pointed slightly above the bearing as shown in Figure 3. The bearing is made from a small 1/16″ nail, or part of a large cotter pin forged to the shape as shown. The hole for the propeller

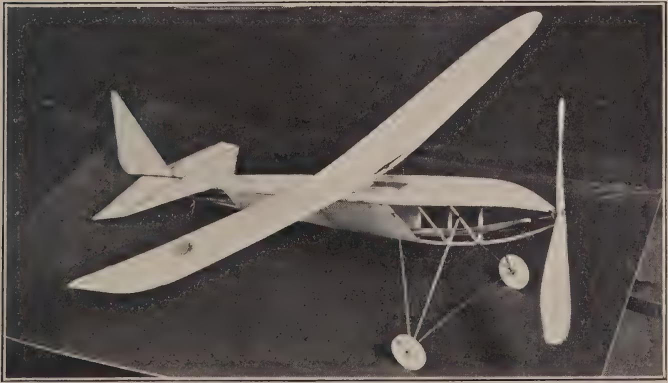


WING TIP CUT OFF TO SHOW METHOD OF ASSEMBLING RIBS TO LEADING AND TRAILING EDGES

Notice that the bamboo tip is a continuation of the wing tip



FRONT VIEW OF INDOOR COMMERCIAL MODEL, SHOWING METHOD OF MOUNTING MOTOR STICK



INDOOR COMMERCIAL MODEL WITH FRONT SECTIONS LEFT UNCOVERED TO SHOW INTERNAL CONSTRUCTION

shaft is .035 of an inch in diameter, and is slotted on one side by carefully filing. This slot must not be as wide as the hole or the propeller shaft will keep slipping out of place, preventing the propeller from turning. The purpose of this slot is to allow the propeller to be removed at will to change the rubber, which would be impossible with this type of fuselage using the ordinary bearing. The propeller shaft is flattened halfway between the hook and the propeller as shown (see Figure 4). The thin part permits it to slip into and out of the slot with ease when changing the motor. When finished, the bearing is ambroided in place. Figure 5 clearly shows the construction of the rear hook which can now be ambroided in place.

We can now assemble the motor stick to the top part of the fuselage. This is done by adding the four small braces that attach the motor stick to the side beams in sections A and C. These pieces should be beveled at the ends to make close joints and should hold the motor stick parallel to the upper side of the fuselage, three eighths of an inch from the bottom of the cross-pieces. (See side view of assembly drawings, Figure 1; also the detailed drawing of nose, Figure 2. Notice that the bearing extends an eighth of an inch out beyond the fuselage.)

We are now ready to assemble the lower beam that forms the apex or bottom edge of the triangular fuselage. The front end of this should be well steamed for about seven inches from the end so that it may be bent upward. The bending may be done by drawing the outline on a sheet of paper mounted on a board. Small brads should be driven in on both sides of the drawing to hold the piece in place while drying. Another way is to ambroid the rear end by means of the small 1/16″ × 1/8″ × 1/2″ balsa upright to the top part of the fuselage and then to complete the triangular sections, D, E, and F, allowing them to dry thoroughly before steaming the front end. When these sections are finished and the ambroid set, the front end may be steamed and the piece bent and held in place by thread while drying. When this piece is dry, the sections B and C may be completed, and the two small 1/32″ × 1/16″ × 3/4″ bamboo braces on the nose ambroided in place (Figure 2). Notice the balsa wedges or spacers ambroided in place under these pieces to keep them parallel and to allow enough room for the rubber motor to be taken out.

The small spring support should now be ambroided in position. This is made from .015 music wire as shown in Figure 5.

We can now assemble the tail group. The elevators and horizontal stabilizer are made in one piece. Two bamboo cross-pieces 1/32″ × 1/16″ are ambroided across the top of the fuselage as shown in the drawing; one of these is nine and the other one eight inches in length. The 9″ one is set 3/4″ from the end of the fuselage and the 8″ one 2 1/2″ from the end.

While these are drying, we can bend the bamboo fin. The shape of this is clearly shown in the side view of the assembled drawings, Figure 1. Split — do not attempt to whittle — a piece of bamboo 1/16″ square from your 15″ piece. When this is carefully trued up and sandpapered, it may be bent as shown. Bamboo, as you know, is very pliable when hot, and can be bent to any desired shape by heating over a candle or alcohol lamp. Experienced model-builders will not have any difficulty here at all, and beginners can make an excellent job with very little practice. When the frame is bent to shape, it is split to form two fins, each 1/32″ thick, the thin side parallel to the paper.

In attaching the fin to the tail groups, the base is ambroided to the two cross-pieces. Notice how the base extends 1/2″ beyond the front edge of the frame of the fin in order to rest on the 8″ cross-piece. The fin should form a right angle with the flat top of the fuselage. Sometimes it is set at a small angle to the thrust line or motor stick, to steer the ship in a smaller circle than it would normally fly in if left straight. As soon as the ambroid on the fin is dry, we can stretch our thread outline around the frame of the stabilizer as shown in the drawing. Every boy has made a kite and used a string to complete the outline around the frame for holding the paper. The thread outline is used in the same manner on this ship. Notice that the end of the thread is tied to the fuselage beams three inches in front of the eight-inch cross-piece and is stretched around the ends of both cross-pieces and to the base of the fin one quarter of an inch beyond the end of the fuselage frame. After being twisted once around the base of the fin, the thread is stretched around the opposite ends of the cross-pieces and back to the fuselage beam, to form the other side of the stabilizer. If you will carefully study the drawings of the top and side views of the ship, you will not have any trouble following the directions given above.

The landing-gear is the next part to construct. This is made from 1/32″ × 1/16″ bamboo. The method of attachment is clearly shown in Figure 1. The four braces are 5 3/4″ in length, and may be split from one piece and the ends bent to fit the side braces of the fuselage. The other ends are joined at the axle which is made from a piece of bamboo 1/32″ × 1/16″ × 7 1/2″. The wheels are cut from 1/8″ flat balsa. A 1 1/2″ circle should be drawn with a pair of compasses, and either with a sharp knife or razor blade the circle cut out to form the wheels. These wheels turn on small axle bearings formed from .020 music wire held in place by ambroiding to the under side of the axle. Small hubs are formed of balsa to prevent the wheels from coming off.

The wing used on this model is the flat or single surface type. A built-up wing may be substituted, but it is extremely doubtful if the added lift, gained by the double surface wing, will equal the added weight and drag due to this type of wing.

The spars are formed from a single piece of balsa 1/8″ × 3/16″ × 26″ long. To form the dihedral angle, this is bent by holding it in the steam from a tea-kettle spout. When dry, it is split lengthwise down the center to form two spars, each identical in shape and size. Care must be used not to spoil these while splitting. A metal-edged ruler will be found helpful in guiding the knife during this operation. The two spars should be finished to 1/8″ in width, well sand-papered, with grooves cut in them so that the ribs will set even with the top side.

The tips are formed from one piece of bamboo 1/16″ ×

1/16″ × 10″. You will find this is longer than necessary, but, as it is hard to bend bamboo so that it will come out just right when cut to length, we always leave the piece long and trim the surplus from the ends. The tips are bent by heating in the same manner as was done with the rudder. They also may be bent around a tin can set over a gas jet or on a hot stove. When the desired shape is obtained, the piece is split to form two tips 1/32″ thick and 1/16″ wide, identical in shape and size. These are fitted into small grooves cut out of the ends of the spars so that the tip will form a continuous curve with them.

Now we are ready to set the seven ribs in place. These are made from bamboo finished to 1/32″ × 1/16″ × 4 1/2″ and fitted into slots or grooves cut in the spars so that they will lie flat with the top of the surface of the wing. The wing can now be covered, on the top side only, with Japanese imperial tissue. The paper should be smooth before beginning, and if wrinkled should be allowed to stand several hours after ironing to prevent any warping or sagging later on. The material used to cover the wing is described in the chapter on 'Wing Construction.' When finished, the paper is trimmed and the rough edges smoothed down by another coat of banana oil applied to the frame. The three wing clips are clearly shown in Figure 7. The large or front ones are a half-inch longer than the single one in the rear. This gives the wing the necessary angle of incidence. Care must be taken to place these equal distances from the center and to see that the two front ones are exactly alike, or the model will not fly.

When the wing clips are set, the three pieces on the fuselage to which they clip may be set in place. The first two are 3/32″ × 1/4″ × 5 3/4″ and the rear or center one is 3/32″ × 1/4″ × 6 3/4″ long. Remember that these must be parallel and fit the clips tightly along their entire length, or the wing will come off in flight. Should these become worn with use, a rubber band passed under the fuselage and over the wing and under the fuselage will help to hold the wing in place.

The fuselage may be covered next. The same method is used as was used in covering the wing. Care should be taken, in cutting the paper to fit the various parts, to make neat joints. The tail surface is covered on the bottom side only; the fin or rudder can be covered on either side. The section of the fuselage between *F* and the rear end is not covered, to allow one to get at the rear hook for winding.

The propeller is carved from a balsa block 7/8″ × 1 1/4″ × 10″. Before you begin, study the five stages shown in the chapter on 'Propellers.'

A six-strand motor, consisting of a piece of 1/8″–32 rubber thread, ten feet long, with the ends tied together in a square knot forming a band, drives the propeller. This is folded to make six strands and one end dropped into the hole in the nose of fuselage and hooked to the rear end by means of the 'S' hook. The other end is looped through the propeller shaft, which is slipped into the bearing, and the ship is ready for flight.

CHAPTER XIV

SCALE MODELS

THERE is a world of difference between building airplane models that fly and scale models. The flying-stick models that have been described are designed to give you the longest possible flight and they do not greatly resemble large ships. When you build a scale model, you pay no attention to flying quality, but attempt to duplicate, as exactly as possible, some large ship.

Genuine scale models seldom fly. The wings, for one thing, are too far forward. On a large ship, the wings must be well forward, to balance the weight of the engine. But there is no engine on a scale model. Of course, on your model, you could set the wing farther back in order to balance the ship — but when you do that, you no longer have a scale model. The scale model, remember, is built to duplicate, exactly, a large ship.

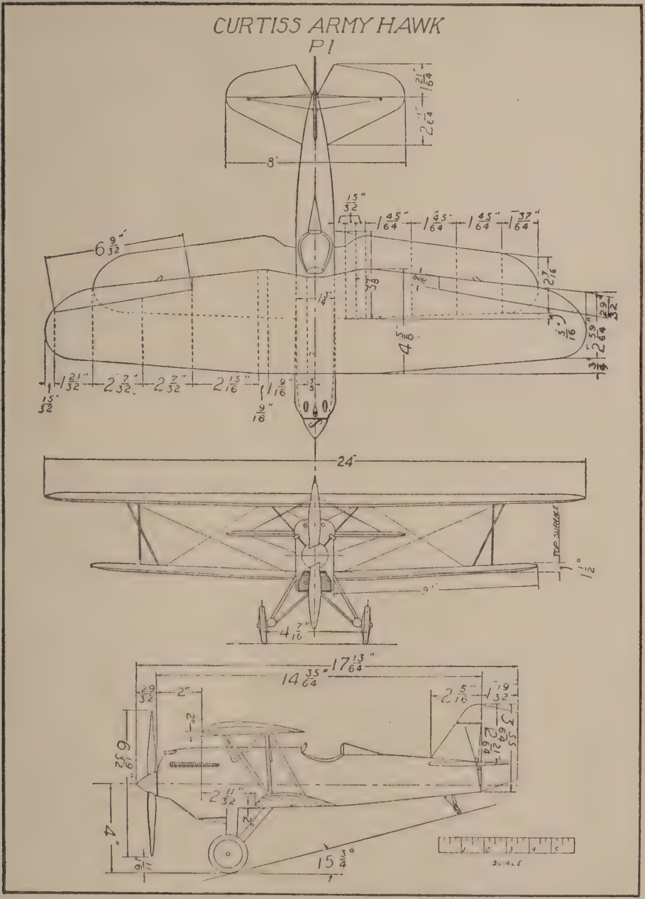
Constructing the scale models described in this article will be a new and extremely worth-while experience. It will teach you the essentials of big ship design. It will test your originality, because the author does not specify just what materials you shall use or how you shall put the planes together. Here are the drawings, scaled down so that the wing of each plane will have a span of just twenty-four inches. All the dimensions in the drawings are in inches. Here, too, are pictures of the planes. The rest is up to you.

Use any method or any available material to build your plane. Some of you will carve most of your ship from solid wood. Others will try to reproduce as nearly as possible the inside structure of the large ship. You may use either method.

Every boy who is reasonably clever with tools can construct satisfactory scale models from the drawings and photographs given here. But as an added help, the Airplane Model League of America has prepared special drawings of the Hawk and Trimotor. Each drawing is scale size — the full size you will want to construct your model. The wings are just twenty-four inches in span, and all other parts are in proportion. The drawing enables you to measure distances on the print itself to obtain the dimensions of any part. On each drawing the airfoil sections are laid out at every point where the trailing edge or leading edge makes a sharp bend. Since the drawing is scale size, the airfoils may be used as templates, or patterns.

Remember that you can't, without great difficulty, reproduce all the inside structure of the big ship. For instance, the Hawk has twenty-six ribs in the upper wing and nineteen in each of the lower wings. That is too many for a model. You should try to reproduce the exterior shape of the ship rather than the inside construction.

The drawings (Nos. 27 and 28) give you the exact shape of the airfoils on these ships. But if you want to study them further, send ten cents to the National Advisory Committee for Aeronautics, Washington, D.C., and ask for Report 244. This contains all details of the Clark Y section, used on the Hawk, and the Göttingen 387, a


CURTISS ARMY HAWK
P1
8"
24"
17 13/64"
14 35/64"
TOP SURFACE
1 1/2°
15 3/4°
4"
SCALE

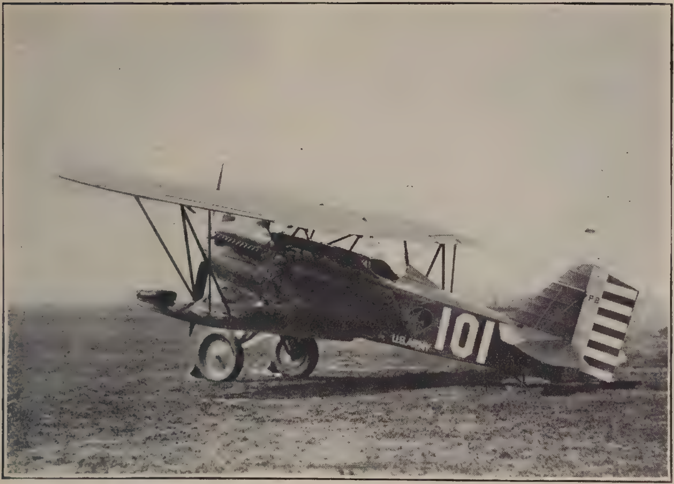
NO. 27

modification of which is used on the Ford Trimotor. If you have studied aeronautics, this report will enable you to lay out your own templates, or patterns, for the ribs on your model. But if you are not an experienced builder, the report will not be very helpful to you.

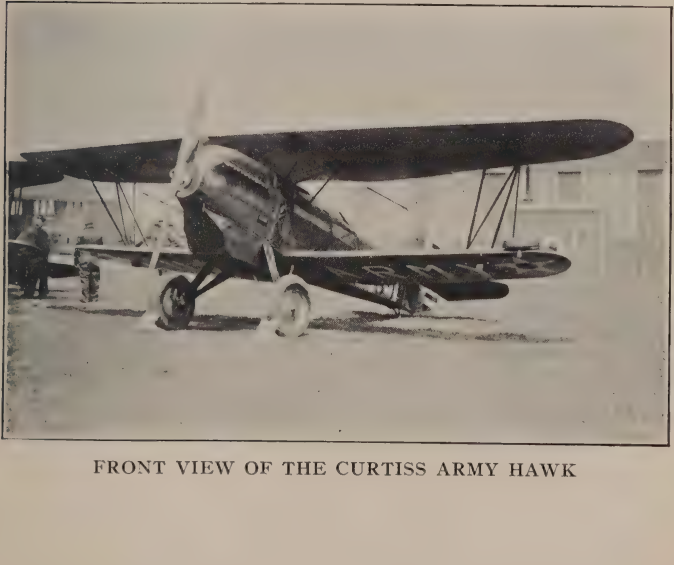
The Curtiss Hawk is the army pursuit ship that has a speed of one hundred and seventy miles an hour. It is one of the best examples of the small, fast, extremely controllable type of plane. It is designed to outfly and outtrick an enemy airplane. Before you start on it, study the drawings and photographs. Notice the radiator under the cowling. Corrugated cardboard, painted over, will do nicely here. For your two gun barrels, you might use 1/8″ tubing, or small wooden pins, painted black. Perhaps the easiest way to reproduce the nose of the ship will be to carve it from a solid block. Remember that no part, such as aileron or propeller, need be movable.

The drawing shows that the lower wing has a dihedral angle of one and one half degrees, measured on the top surface. (The dihedral angle, you will remember, refers to the upward slant of the wings from the center to the tips.) The drawing shows, too, that the upper wing is perfectly flat. From the side view in the drawing you will notice that the upper wing is 2 11/32″ in advance of the lower. In the big ship this enables the pilot to see better ahead and below. It cuts down his blind area — and that is important in air fighting!

Notice, in the photographs, the N–type struts, and their position. Notice the two extra struts — one on each wing — to control the aileron.



SIDE VIEW OF THE CURTISS ARMY HAWK



FRONT VIEW OF THE CURTISS ARMY HAWK

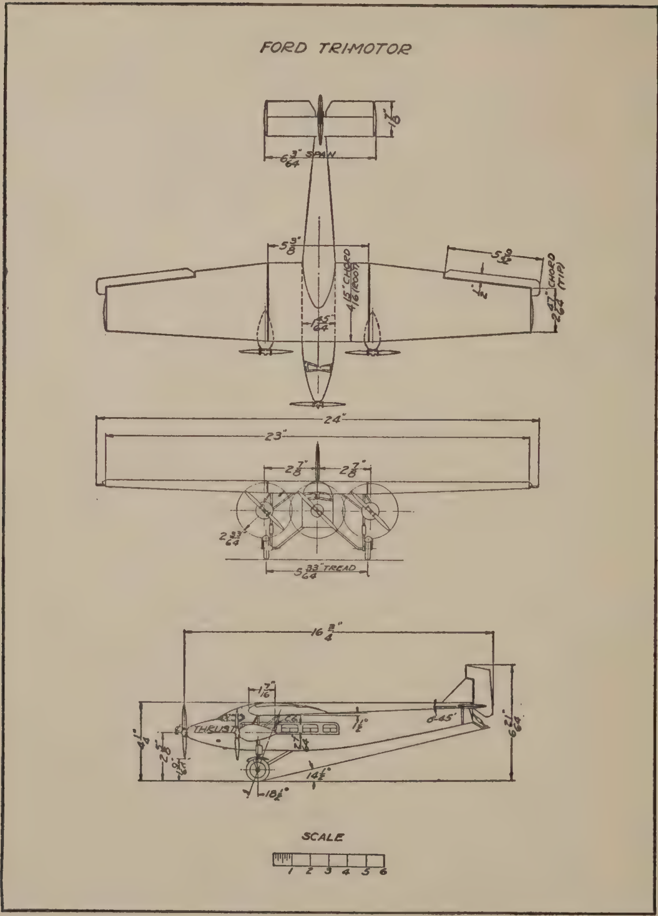
One more point in regard to the wings; each wing has a negative angle of incidence of two degrees. The angle of incidence is the angle between the thrust line and the chord — front-to-rear line — of the wing. The negative angle means that when the ship is in horizontal flight the lower surface of the wing is pointing downward two degrees. Study the side view in the drawing and you will see this point clearly.

When you have finished the ship, paint it an army khaki. There are seven red and six white horizontal stripes on the rudder. The vertical stripe, shown in the photograph at the front of the rudder, is blue.

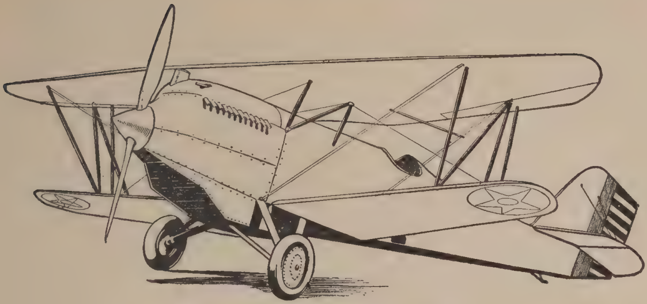
The Ford Trimotor

The Ford three-engine, twelve-passenger transport is built entirely of metal. (It was designed by William B. Stout, president of the Airplane Model League of America.) The metal is corrugated and the corrugations run parallel to the flying direction.

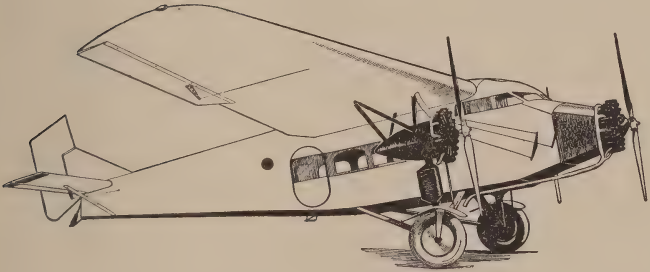
Although you will not want to go into too much detail with the inside construction of this plane, you will be interested to know that the cabin is divided into four separate compartments. Farthest forward is the control cabin, which is entered through a door from the main cabin in the rear. It contains two seats for pilots and two sets of controls. Behind the control cabin and just ahead of the wing is a small observation compartment with windows in the upper half of it. The side picture shows you this clearly. In back of the observation compartment is the main cabin, equipped either with wicker chairs or


FORD TRIMOTOR
6 3/64" SPAN
7/8"
5 5/8"
4 15/16" CHORD (ROOT)
1 45/64"
1/2"
2 47/64" CHORD (TIP)
24"
23"
2 7/8"
2 7/8"
2 33/64"
5 33/64" TREAD
16 3/4"
1 7/16"
THRUST
C.G.
1 1/2°
6.45'
4 1/4"
2 5/8"
1 9/16"
14 1/2°
18 1/2°
SCALE
1 2 3 4 5 6

NO. 28



NO. 29. CURTISS ARMY HAWK



NO. 30. FORD TRIMOTOR

three berths. Behind the main cabin is the washroom and space for luggage.

The door, you will notice, is at the rear of the main cabin on the right side of the ship. There are five windows on the left side of the ship and four on the right.

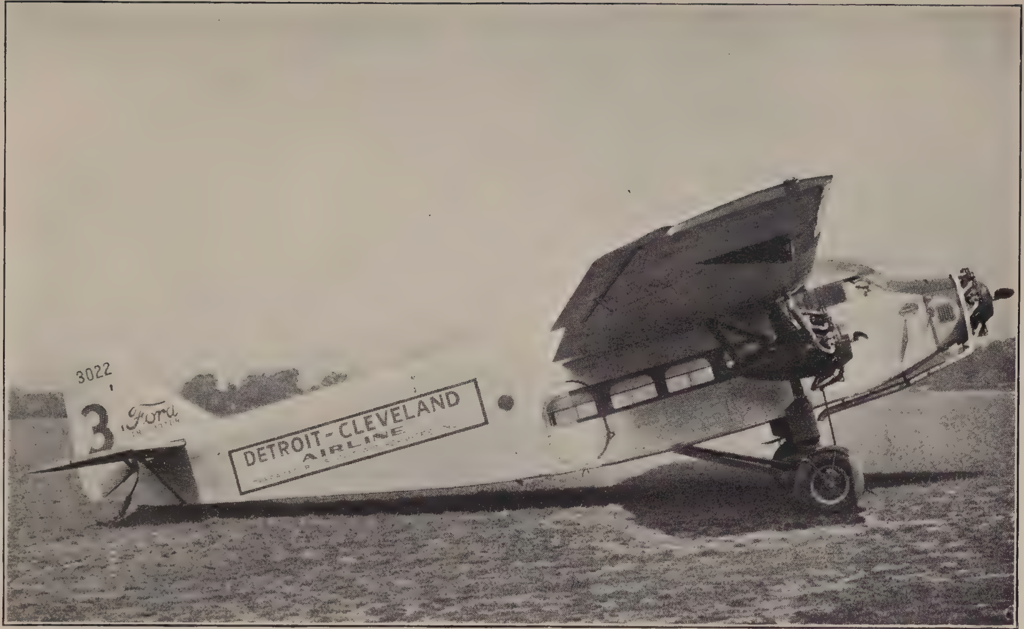
The scale-size drawing of the Stout Trimotor, which you can obtain from the A.M.L.A. for twenty cents, shows you the airfoil section of the wing. If you want to study this section further, you will find it in Report

No. 244, mentioned earlier in the article. The Ford section is a modified Göttingen 387. It differs from the section shown in Report 244 in that the lower surface of the wing is entirely flat and the camber on the upper surface is increased from .1536 of the chord to .2000. This gives you a thicker section. This information will interest you only if you are planning to lay out your own curves instead of following the scale-size drawing furnished by the League. And if you are new at scale model construction, you had better not try laying out your own curves.

Notice, in the photographs and drawings, the streamline landing-gear struts and the oleo cylinder and compression rubber springs on the landing-gear and tail skid.

Your Ford Trimotor, when completed, should be painted a bright aluminum color.

These brief descriptions have called your attention to just a few of the details of these two widely different types of airplanes. The exact process you follow, and the materials you use, depend entirely upon your ingenuity. As you work, keep on the alert to get the location of each part just right. See that your struts and wires are properly placed. See how closely you can duplicate the shape of the wings, the types of propellers, and every other detail. The final result will depend to a great degree upon your accuracy in interpreting the pictures and drawings.



SIDE VIEW OF THE FORD TRIMOTOR

CHAPTER XV

MODEL AIRPLANE CLUB ORGANIZATION

WHENEVER possible, boys interested in building and flying model airplanes should organize a club. Boys who build models in groups will progress much faster than boys working alone. They have the advantage of comparing planes and profiting by each other's experiences. Clubs enable the boys to interest other boys as well as adults, provide groups for contests, encourage research work, and give the boys confidence and experience in flying in competition.

The first step in organization is to assemble all the boys who are interested and elect officers. The suggested constitution given at the end of this chapter may be used as it is or modified to suit the individual needs of your club. The membership should be restricted to fifty members, as a larger group than this becomes unwieldy. Only boys who are definitely planning on constructing models should be admitted, as others will harm rather than help the group. Definite procedure for dropping dead timber should be adopted and the rules strictly enforced.

Obtain, if possible, a definite meeting place. If a clubroom is available, it can be made more attractive by obtaining literature on airplanes, such as books and aviation magazines. A scrapbook should be kept with notes of all the activities of the club, such as newspaper clippings and results of contests. Airplane pictures and, when possible, airplane propellers hung on the wall give a clubroom an attractive appearance. If a separate room for your club cannot be obtained, get permission to meet in your manual training room, after school, at the Y.M.C.A., or in your local church. Almost any organization interested in boys' work will be glad to let you meet in their building as long as the club attends to business and does not misuse the privilege.

Every club should have an adult as sponsor, one who will not only attend your meetings, but will also build planes. Your manual training teacher would be an excellent person to have, as he can help the boys in many ways as well as make valuable suggestions. Scout masters, preachers, and in fact any adult interested in airplanes and boys will do as sponsors.

As soon as your club is organized, affiliate with the Airplane Model League of America, the National Model Organization, and see that each member fills out an application and obtains his membership card and button. Application blanks and club information may be obtained, upon request, from the A.M.L.A. headquarters at 550 Lafayette Boulevard, Detroit, Michigan. A list of all the members, with the information about each and requests for the application blanks, should also be sent in by the secretary of each club, to be filed at the national headquarters.

The A.M.L.A. stands ready to help you organize your club, furnish kits and materials at cost, answer all the questions that you have on aviation, promote contests between clubs, establish categories for contests, and in every way possible aid model-builders.

This organization has the approval of the National Aeronautic Association. It not only has the support of the leaders in aviation, but numbers many of them among its officers. In less than a year the organization has grown from a small group of thirty members to over one hundred and fifty thousand.

Once your club is thoroughly on its feet, you should not have any trouble getting support. You will find, as soon as you have some planes that can be depended on to give real flights at demonstrations, that civic clubs and other organizations will want you to fly for them at their entertainments. Do not attempt to give exhibition flights until you have at least five or six models that will fly not less than thirty or forty seconds. When you are ready, go to the local newspaper, the Rotarians, to the Kiwanis, to Lions, to one or more of the lodges, to the Chamber of Commerce, or some similar organization. Tell them what your club is doing; that your model airplanes will really fly. Prove it to them in their offices. Ten to one they will be interested and invite you to give an exhibition (if not, try another) at their next meeting. After that it is up to you. If you do well, the chances are they will help you to get financial support and possibly to send your local champions to the national contests.

See that your club meetings are interesting. Perhaps you will want to appoint a programme committee to take care of that. Invite men who are interested in aeronautics to talk to you. Lay out a definite programme of experiments, such as rubber tests or propeller research and see that it is carried through. Set aside part of the meeting time for flying and try to instill a spirit of competition at these sessions. Keep a set of club records and award some sort of recognition to the holders of these records.

Possibly you will want to organize the members of your club into groups: some known as ground men, flying cadets, pilots, aces, and assistant instructors. Clubs have worked out excellent plans whereby they can encourage the members to study aviation and to proceed with their model work. Usually in these clubs the new member has to enter as a ground man. In order to pass from one group to the other, he must pass an examination on some phase of aviation as well as to construct certain models with set specifications or requirements. These tests and examinations should be progressive in nature; that is, a beginner would not be expected to build as good an airplane as the advanced student or to know as much about aviation. Many clubs start with the Baby R.O.G. and require that each boy earn his honor certificate from the League before he can become a flying cadet. Then he must construct the indoor pusher and get his certificate before he can become a pilot, etc. Material for the examinations can be obtained from this book, and this gives the student a chance to get all the required information, drawings, etc., from one source.

Exhibitions and contests can be livened up by mixing in stunts. A few suggested ones are given; you will think of a lot more; and you will find that often these stunts furnish more amusement than the main contest.

Balloon 'strafing' always gets a hand from the audience and creates a spirit of competition among the fellows. A number of rubber balloons are suspended from the ceiling by strings. The contestants equip their planes with pin points. These can be pushed through the center of the propeller hub or ambroided to the leading edge of the wing, near the tips. At a given signal the contestants launch their planes toward the balloons attempting to break them by piercing with the pin point. The plane that explodes the most balloons wins the prize. The Baby R.O.G. should be used for this contest, as it makes a faster flight and helps to increase the interest.

Bombs and parachutes can be dropped by many ingenious methods. Some of the boys build small balsa bombs with fins, like the real ones, and, by means of a hook under the fuselage, they are dropped from a great height. The hook is bent so that it will hold the bomb as long as the plane is climbing, but as soon as it levels out the bomb slips off. Small firecrackers can be dropped so that they will explode in the air before landing. This is done by tying the fuse to the fuselage with thread as close to the firecracker as possible. Just before launching the plane, the fuse is lighted and the plane released. When the fuse burns up to the thread, the thread is burnt and the cracker drops. This stunt should never be tried over the heads of an audience, as it would be apt to cause confusion and possibly a panic. When using pins, caution the audience so that they will watch that no one's eyes are put out when the planes land.

The high-climb contest is always interesting, when the room in which the flying takes place has a high ceiling.

Six or seven contestants are lined up and a judge assigned to each. The object is to see whose plane hits the ceiling first. Where it is practicable, the planes can be made to take off under their own power.

Looping-the-loop is another good stunt. The loops should not be counted unless it is a perfect loop. The plane making the most loops in one flight wins. The record so far for models is ten in one flight with eleven additional loops that were not perfect and so could not be counted.

In all stunts and contests the planes should have certain restrictions to regulate their size and to even up the contest. A Baby R.O.G. with an eight-inch fuselage would not have a chance in stunting or endurance against a plane with a ten-inch stick. In Appendix I are given the rules used at all national contests for duration planes. They have been found to be very workable, and you can base your rules on these using the same restrictions.

A SUGGESTED AIRPLANE MODEL CLUB CONSTITUTION

ARTICLE I — NAME

This club shall be known as the . . . . . . Chapter of the Airplane Model League of America.

ARTICLE II — OBJECT

The object of this club shall be to promote model aviation.

ARTICLE III — MEMBERSHIP

Any person over . . . . . . years of age may become a member of this club upon receiving a majority vote of the members present at any regular meeting.

ARTICLE IV — OFFICERS

The officers of this club shall be: President, Vice-President, Secretary, Treasurer, Sergeant-at-Arms, and Advisor. They shall be elected every six months by a majority vote of the members present. (The advisor should be an interested adult, skilled in promoting activities.)

ARTICLE V — DUTIES OF OFFICERS

SECTION 1. The president shall preside at all meetings of the club.

SECTION 2. The vice-president shall preside in the absence of or at the request of the president.

SECTION 3. The secretary shall keep the minutes of the proceedings of the club and conduct the correspondence.

SECTION 4. The treasurer shall keep a record of all money received, spent and on hand, and pay only such sums as shall be authorized by the club, and upon order signed by the president and secretary. He shall make a report in writing at each meeting of all money received, spent, and on hand.

SECTION 5. It shall be the duty of the sergeant-at-arms to assist in keeping order.

SECTION 6. It shall be the duty of the advisor to assist the club in its programme of activities.

ARTICLE VI — COMMITTEES

SECTION 1. There shall be a Programme Committee which will, with the approval of the president, arrange for interesting programmes.

SECTION 2. There shall be a Research Committee for investigating and experimenting on new material and new design and reporting its findings to the club.

ARTICLE VII — MEETINGS

SECTION 1. The club shall hold a meeting every ......

SECTION 2. Special meetings may be called by the president at the written request of five members.

Article VIII — Dues

The dues of this club shall be . . . . . . cents each regular meeting. (The club collects money for its own purposes only; it pays no dues to the A.M.L.A.)

Article IX — Order of Meeting

The order of exercises shall be as follows:

1. Call to order
2. Roll Call
3. Reading of Minutes
4. Treasurer's Report
5. Reports of Committees
6. Unfinished Business
7. New Business
8. Adjournment

Article X — Parliamentary Law

'Cushing's Manual' shall be the parliamentary authority of the club.

Article XI — Amendments

This constitution may be altered or amended by a two-thirds vote of the members present.

APPENDIX

I

RULES FOR THE STOUT INDOOR CONTEST

Sanctioned by the National Aeronautic Association under Rules of the Fédération Aéronautique Internationale

The William B. Stout trophy shall be competed for annually by members of the Airplane Model League of America, or other nationally recognized model aero clubs using hand-launched model airplanes, driven by rubber strand motors. The trophy shall be awarded each year to the club, body or chapter represented by the entrant who builds and flies the winning model, and this body shall be entitled to the possession of the trophy until one month prior to the next contest, at which time the trophy shall be returned to the contest committee of the A.M.L.A. Suitable bond or guarantee for its proper care and return shall be required from each and every person or organization into whose possession the trophy shall be delivered.

The trophy will become the permanent possession of any club, body, or chapter that wins it three times.

Conditions of the Contest

1. No restrictions on the design of the model except that it shall have a distance between the propeller bearing and the motor hook, fastened to the opposite end of the motor stick, not to exceed fifteen inches.

All models must be hand-launched, and the only motive power be derived from the use of rubber strands.

2. The contest will be for duration. A contestant will be allowed a total of three official flights. He will be accredited with the greatest elapsed time made in any one of his three flights.

3. A contestant will be allowed a maximum of three models, and he may use any or all to complete his official three flights.

4. No contestant shall launch his model before receiving the launch-signal from the official starter. Any contestant doing so will be disqualified. All contestants must have their models ready for examination by the officials fifteen minutes before the starting time of the contest.

Each contestant will draw a number, giving his place in rotation. He will be allowed two minutes within which to launch his model. Should he fail to launch his model in the time allowed he must withhold that official trial until his next turn in line and a delayed flight will be charged against him.

5. Any flight under fifteen seconds and every failure to fly in turn shall be considered a delayed flight. Three delayed flights will be considered an official flight.

6. The finish time will be taken when the model strikes or lands on any object preventing further flight.

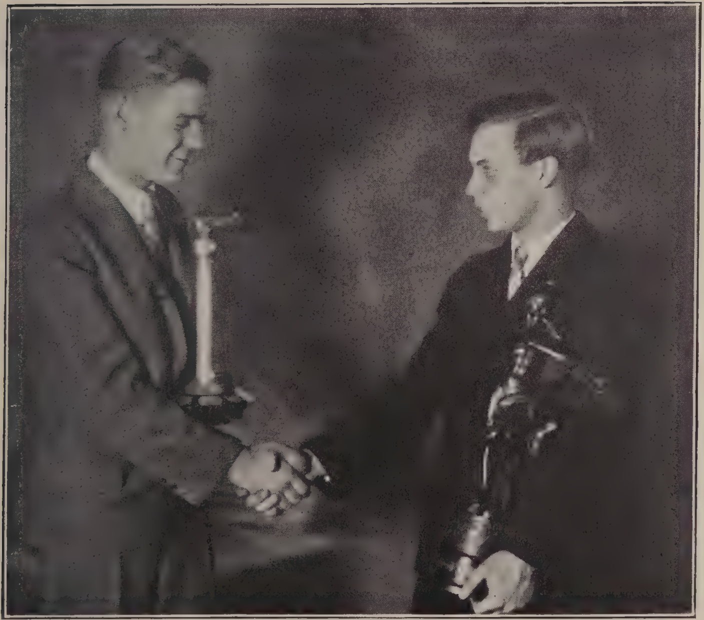
7. The winner of first place shall be the owner and builder of the model which has remained in flight for the longest time; and of second place, the second longest elapsed time, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize; each contestant will be allowed only the prize to which his best flight entitles him.

8. No contestant may take part in this contest unless he is a member of the Airplane Model League of America or some nationally recognized model aero club using hand-launched model airplanes, driven by rubber strand motors. He must also be the owner and builder of the models submitted. However, the design of the model may be obtained from other sources than his own. He shall be the builder of the entire model with the exception of the thrust bearings and thrust washers which may be purchased from other sources.

(*Note:* Users of A.M.L.A. kits are eligible.)

9. Any contestant breaking the rules of the race, or subsequent ones which may be sent out in writing, shall upon the recommendation of the officials, be disqualified. Models broken upon landing will not be disqualified.

10. No protest shall be considered unless presented to the



CHARLES DYBVIG, LEFT, 1927 WINNER OF THE STOUT NATIONAL INDOOR TROPHY, AND JACK LOUGHNER, 1926–27 OUTDOOR CHAMPION AND HOLDER OF THE MULVIHILL TROPHY CONGRATULATE EACH OTHER

contest committee in writing within twenty-four hours after the finish of the race.

11. Minimum number of contestants eight. Maximum number of contestants twenty-five. (This applies only to the finals.)

RULES FOR THE MULVIHILL OUTDOOR CONTEST

Sanctioned by the National Aeronautic Association under Rules of the Fédération Aéronautique Internationale

(*a*) The trophy shall be perpetual and competed for annually by members of the Airplane Model League of America, or other model aero clubs recognized by the National Aeronautic Association, using hand-launched model airplanes, driven by rubber strand motors.

(*b*) The trophy shall be awarded each year, to the club, body, or chapter represented by the entrant of the winning model, and this body shall be entitled to the possession of the trophy until one month prior to the next succeeding contest, at which time the trophy shall be returned to the National Aeronautic Association; suitable bond for its proper care and return shall be required by the donee (the N.A.A.), from each and every person or organization into whose possession the trophy shall at any time be delivered.

Conditions of Contest

No restrictions on the design of the model except that it shall have a wing span not to exceed 40 inches. All models must be hand-launched and the only motive power will be that derived from the use of rubber bands.

Character of Contest

The contest shall be for duration. A contestant will be allowed a total of three official flights. He will be accredited with the greatest elapsed time made in any one of his three flights.

NUMBER OF ENTRIES PER CONTESTANT

A contestant will be allowed a maximum of three models, and he may use any or all to complete his official three flights.

METHOD OF STARTING

No contestant shall launch his model before receiving the launching-signal from the official starter. Any contestant doing so will be disqualified.

All contestants must have their models ready for examination by the judges by 9.00 A.M. Contests will start at 9.30 A.M. Judges shall select the place of starting previous to contest. Each contestant will draw a number giving his place in rotation of starting. The same rotation will follow until each contestant has completed his three official flights. The time of starting of each contestant will be posted ten minutes in advance.

He will be allowed five minutes within which to launch his model. Should he fail to launch his model within the time allowed, he shall be charged with a delayed flight and he must withhold that official trial until his next turn in line. Any flight under ten seconds will not be official and will count as a delayed flight. Three delayed flights shall count as an official flight.

FINISH

The finishing time will be taken when the model first touches the ground after being launched or when it passes out of sight of officials.

WINNERS

The winner of first place shall be the owner and builder of the model which has remained in flight for the longest elapsed time, and of second place the second longest elapsed time, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize. To distribute the prizes more evenly, each contestant will be allowed only the prize to which his best flight entitles him.

QUALIFICATIONS

No contestant may take part in the contest for this trophy unless he is a member of the Airplane Model League of America or other model Aero club recognized by the N.A.A. and in good standing. He must also be the owner and builder of the model submitted. However, the design for the model may be obtained from other sources than his own. He shall be the builder of the entire model with the following exceptions: Propellers, motor bearings and propeller shaft; also such other small metal fittings as may be used in the construction of the model may be purchased from outside sources.

DISQUALIFICATIONS

Any contestant breaking the rules of the race, or subsequent ones which may be sent out in writing, shall, upon recommendation of the judges, be disqualified. Models broken upon landing will not be disqualified.

PROTESTS

No protest shall be considered unless presented in writing to the Contest Committee within twenty-fours after the finish of the race. (F.A.I. Rules, 78, 79, 80.)

RULES FOR THE SCALE MODEL CONTEST

(*a*) The trophy shall be competed for annually by members of the Airplane Model League of America or other nationally recognized model airplane clubs building exact scale models.

CONDITIONS OF CONTEST

(1) There will be no restrictions as to the design of the ship except that it must be an exact replica of a man-carrying airplane and have an exact wing span, including ailerons, of twenty-four inches.

The models do not have to fly, nor need any parts such as propellers, wheels, etc., be movable. Neither is it necesary to use the same material in construction as employed on the large ship.

(2) The contest will be for workmanship, originality in obtaining the desired resemblance to the man-carrying ship, the exactness to which the model is scaled and any other points which are, in the opinion of the judges, important in such a contest.

(3) Each contestant will be allowed to submit one model and unless the model is made from drawings previously checked by the Contest Committee of the A.M.L.A., it must be accompanied by a drawing giving all necessary dimensions, airfoil sections and such other details as may be considered necessary by the judges in order to construct a model. This drawing must be one supplied by the manufacturer of the airplane, after which the plane was modeled, or be accompanied by a letter from the company building the plane, stating that the manufacturer or his representative has checked the drawing and found it to be correct.

(4) All planes and drawings must be in the hands of the Contest Committee at least two weeks before the date of the contest.

(5) The winner of first place shall be the owner and builder of the model which in the judgment of the officials is the best example of workmanship as defined by the rules, and of second place the next best example of workmanship, etc., providing the contestant has not been disqualified. No individual will be allowed more than one cash prize; each contestant will be allowed only the cash prize to which his place entitled him.

(6) No contestant may take part in this contest unless he is a member of the A.M.L.A. or some other nationally recognized model airplane club. He must be the owner and builder of the entire model submitted.

(7) Any contestant breaking the rules of the contest or subsequent ones which may be sent out in writing, shall upon the recommendations of the officials be disqualified.

(8) No protests shall be considered unless presented to the Contest Committee in writing within twenty-four hours after the finish of the contest.

(9) Minimum number of contestants eight.

II

NOMENCLATURE FOR AERONAUTICS

Aerodynamics — The branch of dynamics which treats of the motion of air and other gaseous fluids and of the forces acting on solids in motion relative to such fluids.

Aeronautics — The science and art pertaining to the flight of aircraft.

Aerostatics — The science that treats of the equilibrium of gaseous fluids and of solid bodies immersed in them. As an aeronautic term, it relates to those properties of lighter-than-air craft which are due to the buoyancy of the air.

Aerostation — The art of operating aerostats.

Aileron — A hinged or pivoted movable auxiliary surface of an airplane, usually part of the trailing edge of a wing, the primary function of which is to impress a rolling moment on the airplane.

Aircraft — Any weight-carrying device or structure designed to be supported by the air, either by buoyancy or by dynamic action.

Airfoil — Any surface designed to be projected through the air in order to produce a useful dynamic reaction.

Airfoil section (or **profile**) — A cross-section of an airfoil made by a plane parallel to a specified reference plane. A line perpendicular to this plane is called the axis of the airfoil.

Airplane — A mechanically driven aircraft, heavier than air, fitted with fixed wings, and supported by the dynamic action of the air.

Airplane, Pusher — An airplane with the propeller or propellers in the rear of the main supporting surfaces.

Airplane, Tandem — An airplane with two or more sets of wings of substantially the same area (not including the tail unit) placed one in front of the other and on about the same level.

Airplane, Tractor — An airplane with the propeller or propellers forward of the main supporting surfaces.

Airport — A locality, either of water or land, which is adapted for the landing and taking off of aircraft and which provides facilities for shelter, supply, and repair of aircraft; or a place used regularly for receiving or discharging passengers or cargo by air.

Air scoop — A projecting scoop which uses the wind or slip stream to maintain air pressure in the interior of the ballonet of an aerostat. A similar device is sometimes used on airplanes to produce ventilation.

Airship — An aerostat provided with a propelling system and with means of controlling the direction of motion. When its power plant is not operating, it acts like a free balloon.

Non-rigid — An airship whose form is maintained by the internal pressure in the gas bags and ballonets.

Rigid — An airship whose form is maintained by a rigid structure.

Semi-rigid — An airship whose form is maintained by means of a rigid or jointed keel in conjunction with internal pressure in the gas containers and ballonets.

The term 'airship' is sometimes incorrectly applied to heavier-than-air craft either in full or as 'ship.' This is a slang use of the word and should be avoided.

Air speed — The speed of an aircraft relative to the air.

Air-speed meter —

Air-speed indicator — An instrument for indicating the speed of an aircraft relative to the air. It is actuated by the pressure developed in a suitable pressure nozzle or against a suitable obstruction and is graduated to give true air speed at a standard air density.

The speed indicated by the instrument is termed the 'indicated air speed.' The indicated speed is a direct measure of the lift or drag exerted on the airplane at any altitude. (Stalling at all altitudes occurs for the same value of the indicated speed.)

True air-speed meter — An instrument for measuring the true speed of an aircraft relative to the air. The Biram and Robinson anemometers are of this type.

Airway — An air route between air traffic centers, which is over terrain best suited for emergency landings, with landing-fields at intervals equipped with aids to air navigation and a communication system for the transmission of information pertinent to the operation of aircraft.

The term 'airway' may apply to an air route for either landplanes or seaplanes or both.

Alarm-gas-cell — A device, fitted adjacent to a gas cell, which indicates or warns when a predetermined limiting pressure has been reached in the gas cell. Also called 'pressure alarm.'

Altigraph — An altimeter equipped with a recording mechanism. Present instruments are of the aneroid type. The chart, driven by clockwork, is usually graduated in feet or meters in accordance with some empirical or arbitrary pressure-temperature-altitude formula. In other words, it is a barograph whose scale is designed to read heights.

Altimeter — An instrument for measuring or indicating the elevation of an aircraft above a given datum plane. Sea level is usually chosen as the datum plane.

Amphibian — An airplane designed to rise from and alight on either land or water.

Anchor, sea — An open fabric bag carried on an aircraft and arranged to offer considerable resistance when towed mouth-first through the water. Tripping or collapsing devices may be incorporated in it. Also called 'drogue.'

Anemometer — An instrument for indicating or measuring the speed of an air stream.

Angle, aileron — The angular displacement of an aileron from its neutral position. It is positive when the trailing edge of the aileron is below the neutral position.

Angle, critical — An angle of attack at which the flow about an airfoil changes abruptly with corresponding abrupt changes in the lift and drag.

Angle, downwash — The angle through which an air stream is deflected by any lifting surface of an airplane. It is measured in a plane parallel to the plane of symmetry and is denoted by the symbol ϵ.

Angle, drift — The horizontal angle between the longitudinal axis of an aircraft and its path relative to the ground.

Angle, elevator — The angular displacement of the elevator from its neutral position. It is positive when the trailing edge of the elevator is below the neutral position.

Angle, landing — The acute angle between the line of thrust of an airplane and the horizontal when the airplane is resting on level ground in its natural position. Also called 'ground angle.'

Angle, longitudinal dihedral — The difference in angle of wing setting and of stabilizer setting. (This angle is positive when the angle of stabilizer setting, referred to the thrust line, is less than the angle of wing setting.)

Angle, minimum gliding — The acute angle between the horizontal and the most nearly horizontal path along which an airplane can descend steadily in still air when the propeller is giving no thrust.

Angle of attack — The acute angle between the chord of an airfoil and its direction of motion relative to the air. (This definition may be extended to other bodies than airfoils.) Its symbol is α.

Angle of pitch — The acute angle between two planes defined as follows: One plane includes the lateral axis of the aircraft and the direction of the relative wind; the other plane includes the lateral axis and the longitudinal axis. (In normal flight the angle of pitch is, then, the angle between the longitudinal axis and the direction of the relative wind.) This angle is denoted by θ and is positive when the nose of the aircraft has risen.

Angle of roll, or **angle of bank** — The acute angle through which an aircraft must be rotated about its longitudinal axis in order to bring its lateral axis into a horizontal plane. This angle is denoted by ϕ and is positive when the left wing is higher than the right.

Angle of stabilizer setting — The acute angle between the line of thrust of an airplane and the chord of the stabilizer.

Angle of wing setting — The acute angle between the plane of wing chord and the line of thrust. It may differ for each wing.

Angle of yaw — The acute angle between the direction of the relative wind and the plane of symmetry of an aircraft. This angle is denoted by ψ and is positive when the aircraft has turned to the right.

Angle, propeller-blade — The acute angle between the chord of a propeller section and a plane perpendicular to the axis of rotation of the propeller. Usually called 'blade angle.'

Angle, rudder — The acute angle between the rudder and the plane of symmetry of the aircraft. It is positive when the trailing edge has moved to the left with reference to the normal position of the pilot.

Angle, wing-dihedral, or **dihedral** — The acute angle between the transverse reference line in the wing surface and the lateral axis of the airplane projected on a plane perpendicular to the longitudinal axis. The dihedral angle is positive when the upper obtuse angle for the two wings is less than 180°.

Angle, zero-lift — The angle of attack of an airfoil when its lift is zero.

Apparatus, water-recovery — Apparatus carried on an airship for condensing and recovering the water contained in the exhaust gases of internal combustion engines in order to avoid the necessity of valving gas as the fuel is consumed.

Appendix — The tube, usually located at the bottom of a balloon, primarily used for inflation and deflation. In the case of a free balloon it may also serve as an automatic-discharge opening. Originally applied to free balloons only. Should be restricted to the various types of balloons and not applied to airships.

Apron — A hard surface area of considerable extent immediately in front of the entrance of a hangar or aircraft shelter which is used for the handling of aircraft or for repair in clear weather.

Aspect ratio — The ratio of span to mean chord of an airfoil; that is, the ratio of the square of the maximum span to the total area of an airfoil.

Aspect ratio of propeller blade — Half the ratio of propeller diameter to maximum blade width.

Aviation — The art of operating heavier-than-air craft.

Axes of an aircraft — Three fixed lines of reference, usually centroidal and mutually perpendicular. The longitudinal axis in the plane of symmetry, usually parallel to the axis of the propeller, is called the longitudinal axis; the axis perpendicular to this in the plane of symmetry is called the normal axis; and the third axis perpendicular to the other two is called the lateral axis. In mathematical discussions, the first of these axes, drawn from front to rear, is called the X axis; the second, drawn upward, the Z axis; and the third, running from right to left, the Y axis.

Balanced surface — A control surface which extends on both sides of the axis of the hinge or pivot in such a manner as to reduce the moment of the air forces about the hinge.

Ballast — Any substance, usually sand or water, carried in a balloon or airship and intended to be thrown out, if necessary, for the purpose of reducing the load carried and thus altering the aerostatic relations.

Ballonet — A compartment of variable volume constructed of fabric, or partitioned off, within the interior of a balloon or airship. It is usually partially inflated with air, under the control of valves, from a blower or from an air scoop. By the blowing in or letting out of air, it serves to compensate for changes of volume in the gas contained in the envelope and to maintain the gas pressure, thus preventing deformation or structural failure. By means of two or more ballonets, often used in non-rigid airships, the trim can also be controlled. The ballonet should not be confused with gas cell.

Balloon — An aerostat without a propelling system.

Barrage — A small captive balloon, used to support wires or nets which are intended as a protection against attacks by aircraft.

Captive — A balloon restrained from free flight by means of a cable attaching it to the earth.

Free — A balloon, usually spherical, whose ascent and descent may be controlled by use of a ballast or with a loss of the contained gas, and whose direction of flight is determined by the wind.

Kite — An elongated form of captive balloon, fitted with lobes to keep it headed into the wind and usually deriving increased lift due to its axis being inclined to the wind.

Observation — A captive balloon used to provide an elevated observation post.

Propaganda — A small free balloon sent up without passengers but with a device by which papers or documents may be dropped at intervals.

Bank — To incline an airplane laterally, i.e., to rotate it about its longitudinal axis. Right-bank is to incline the airplane with the right wing down. Also used as a noun to describe the position of an airplane when its lateral axis is inclined to the horizontal.

Barograph — An instrument for recording the barometric or static pressure of the atmosphere.

Basket — The structure suspended beneath a balloon, for carrying passengers, ballast, etc. It is usually used on a free or kite balloon.

Bay (body-parts) — The portion of a face of a truss, or of a fuselage, between adjacent bulkheads or adjacent struts or frame positions.

Biplane — An airplane with two main supporting surfaces placed one above the other.

Blade back — The side of a propeller blade which corresponds to the upper surface of an airfoil.

Blade face — The surface of a propeller blade which corresponds to the lower surface of an airfoil. Sometimes called 'thrust face' or 'driving face.'

Blade-width ratio — The ratio of the developed width of a propeller blade at any point to the circumference of a circle whose radius is the distance of that point from the propeller axis.

Blimp — A small non-rigid airship. 'Airship' is to be preferred.

Body — The fuselage or hull, or nacelle (including cowling and covering) and nacelle mounting.

Breathing — The passage of air into or out of an aerostat, due to the changing of its volume.

Buoyancy — The upward air force on an aerostat which is derived from aerostatic conditions.

Cabane — A framework for supporting the wings at the fuselage; also applied to the system of trussing used to support overhang in a wing.

Camber — The rise in the curve of an airfoil section from its chord, usually expressed as the ratio of the departure of the curve from the chord, to the length of the chord. 'Upper camber' refers to the upper surface of an airfoil and 'lower camber' to the lower surface; 'mean camber' is the mean of these two.

Car — That portion of an airship which is intended to carry power unit or units, personnel, cargo or equipment. It may be suspended from the buoyant portion, or it may be built close up against it. It is not to be applied to parts of the keel of a rigid or semi-rigid airship which have been fitted for the purposes mentioned.

Ceiling —

Absolute — The maximum height above sea level at which a given airplane would be able to maintain horizontal flight, assuming standard air conditions.

Service — The height above sea level, assuming standard air conditions, at which a given airplane ceases to be able to rise at a rate higher than a small specified one (100 feet per minute in the United States and England). This specified rate may be different in different countries.

Center of pressure coefficient — The ratio of the distance of the center of pressure from the leading edge to the chord length.

Center of pressure of an airfoil section — The point in the chord of an airfoil section, prolonged if necessary, which is at the intersection of the chord and the line of action of the resultant air force. Its abbreviation is C.P.

Chord (of an airfoil section) — The line of a straight edge brought into contact with the lower surface of the section at two points; in the case of an airfoil having double convex camber, the straight line joining the leading and trailing edges. (These edges may be defined, for this purpose, as the two points in the section which are farthest apart.) The method used for determining the chord should always be explicitly stated for those sections with regard to which any question seems likely to arise.

Chord length — The length of the projection of the airfoil section on its chord. Its symbol is C.

Chord, mean of a wing — The quotient obtained by dividing the wing area by the extreme dimension of the wing projection at right angles to the chord.

Cockpit — The open spaces in which the pilot and passengers are accommodated. When the cockpit is completely housed in it is called a cabin.

Compartment, control — A compartment in the control car of an airship from which all controls are operated. It may be compared to the pilot house of a ship.

Compass, induction — A compass, the indications of which depend on the current generated in a coil revolving in the earth's magnetic field.

Condenser, water-recovery — That part of the water-recovery apparatus which is devoted to the condensing of water in the exhaust gases. It may consist of a number of metal tubes or of a fabric box with appropriate inlets, outlets, and baffles.

Controllability — The quality in an airplane which makes it possible for the pilot to change its attitude easily and with the exertion of but little force.

Controls — A general term applied to the means provided to enable the pilot to control the speed, direction of flight, attitude, and power of an aircraft.

Air controls — The means employed to operate the control surfaces of the aircraft.

Control stick — The vertical lever by means of which the longitudinal and lateral controls of an airplane are operated. Pitching is controlled by a fore-and-aft movement of the stick, rolling by a side-to-side movement.

Cover, outer — The outside covering of the hull of a rigid airship, usually of some kind of fabric. Sometimes called the 'envelope.'

Cowling — A removable covering which extends over or around the engine, and sometimes over a portion of the fuselage or nacelle as well.

Crew, landing — A detail of men necessary for the landing and handling of an airship on the ground. A 'ground crew.'

Deflation — The act of removing gas and air from an aerostat.

Dirigible — That can be directed; steerable; as a dirigible balloon. Its use as a noun to indicate an airship is improper.

Dive — A steep descent, with or without power, in which the air speed is greater than the maximum speed in horizontal flight.

Dope (airplane) — The liquid material applied to the cloth surfaces of airplanes to increase strength, to produce tautness by shrinking, and to act as a filler for maintaining airtightness.

Dope (airship) — The liquid material applied to rubberized airship fabric to increase gas tightness. In contrast with airplane dope, it does not cause shrinking.

Dope (pigmented) — An aircraft dope to which a pigment has been added to make an opaque finish, or to protect it from the effects of sunlight.

Drag — The component parallel to the relative wind of the total air force on an aircraft or airfoil. Its symbol is D.

In the case of an airplane, that part of the drag due to the wings is called 'wing drag'; that due to the rest of the airplane is called 'structural drag' or 'parasite resistance.'

Induced — That portion of the wing drag induced by, or resulting from, the generation of the lift.

Profile — That portion of the wing drag which is due to friction and turbulence in the fluid and which would be absent in a non-viscous fluid.

Duralumin — An alloy of aluminum which is much used in aeronautics, especially for the structure of airships and airplanes. Its chemical composition and physical properties are about as follows:

Copper, 3.5 to 4.5 per cent
Manganese, 0.4 to 1 per cent
Magnesium, 0.2 to 0.75 per cent
Aluminum, 92 per cent, minimum
Tensile strength, ultimate, 55,000 pounds per square inch.
Tensile strength at elastic limit, 30,000 pounds per square inch.
Elongation of two inches at ultimate strength (test specimen half inch wide), 18 per cent.
Specific gravity not more than 2.85.

Elevator — A movable auxiliary airfoil, the function of which is to impress a pitching movement on the aircraft. The elevator is usually hinged to the stabilizer.

Endurance — The maximum length of time an aircraft can remain in the air at a given speed and altitude.

Engine, left-hand — An engine whose propeller shaft, to an observer facing the propeller from the anti-propeller end of the shaft, rotates in a counter-clockwise direction.

Engine, radial — An engine having stationary cylinders arranged radially around a common crank shaft.

Engine, right-hand — An engine whose propeller shaft, to an observer facing the propeller from the anti-propeller end of the shaft, rotates in a clockwise direction.

Engine, rotary — An engine having revolving cylinders arranged radially around a common crank shaft.

Engine, supercharged — An engine with mechanical means for increasing the cylinder charge beyond that normally taken in at the existing atmospheric pressure and temperature.

Engine, vertical — An engine having its cylinders arranged vertically above the crank shaft.

Engine, V-type — An engine having its cylinders arranged in two rows, forming, in the end view, the letter 'V.'

Engine, W-Type — An engine having its cylinders arranged in three rows, forming in the end view, the letter 'W.' Sometimes called the 'broad-arrow type.'

Envelope — The outer covering of an aerostat, usually of fabric. It may or may not be also the gas container. It may be divided by diaphragms into separate gas compartments or cells, and it may also contain internal air cells or ballonets.

Fabric, balloon — The finished material, usually rubberized, of which balloon or airship envelopes are made.

Biased — Plied fabric in which the threads of the plies are at an angle to each other.

Parallel — Plied fabric in which the threads of the plies are parallel to each other.

Fin — A fixed surface, attached to a part of the aircraft, parallel to the longitudinal axis, in order to secure stability; for example, tail fin, skid fin, etc. Fins are sometimes adjustable.

Float — A completely enclosed water-tight structure attached to an aircraft in order to give it buoyancy and stability when in contact with the surface of the water. In float seaplanes the crew is carried in a fuselage or nacelle separate from the float. The term 'pontoon' is now obsolete.

Flying boat — A form of seaplane supported, when resting on the surface of the water, by a hull or hulls providing flotation in addition to serving as fuselages. For the central hull type, lateral stability is usually provided by wing tip floats. The term 'boat seaplane' is now obsolete.

Fuselage — The structure, of approximately streamline form, to which are attached the wings and tail unit of an airplane. In general it contains the power plant, passengers, cargo, etc.

Gap — The distance between the planes of the chords of any two adjacent wings, measured along a line perpendicular to the chord of the upper wing at any designated point of its leading edge. Its symbol is G.

Gear, flotation — An emergency gear attached to a landplane to permit alighting on the water and to provide buoyancy when resting on the surface of the water.

Glide — A descent with reference to the air at a normal angle of attack and without engine power sufficient for level flight in still air, the propeller thrust being replaced by a component of gravity along the line of flight. Also used as a verb.

Glider — A form of aircraft similar to an airplane, but without a power plant.

Hangar — A shelter for housing aircraft. More properly applied to heavier-than-air craft.

Helicopter — A form of aircraft whose sole support in the air is derived directly from the vertical component of the thrust produced by rotating airfoils.

Horn — A short lever attached to a control surface of an aircraft. For example, aileron horn, rudder horn, elevator horn.

Hull (seaplane) — The portion of a flying boat which furnishes buoyancy when in contact with the surface of the water. It contains accommodations for the crew and passengers, usually incorporating the functions of a float and fuselage in one unit.

Keel (airship) — The assembly of members at the bottom of the hull of a semi-rigid or rigid airship which provides special strength to resist hogging and sagging and also serves to distribute the effect of concentrated loads along the hull. It may be a simple Gall's chain, as in some semi-rigids, or a very extensive structure enclosing the corridor, as in most rigids.

Kite — An aircraft heavier than air, restrained by a tow-line and sustained by the relative wind.

Landing-field — A field of such a size and nature as to permit of aircraft landing and taking off in safety. It may or may not be part of an airport.

Landing-field, emergency — A locality, either of water or land, which is adapted for the landing and taking-off of aircraft, but which is not equipped with facilities for shelter, supply, and repair of aircraft and is not used regularly for the receipt or discharge of passengers or cargo by air.

Landing-gear — The understructure which supports the weight of an aircraft when in contact with the surface of the land or water and reduces the shock on landing. There are five common types — boat type, float type, skid type, wheel type, and ski type. (Amphibian may be a combination of the float or boat type with wheels or skis.)

Landing T — A large symbol shaped like a capital 'T' which is laid out on a landing-field or on the top of a building to guide operators of aircraft in landing and taking off.

Landplane — An airplane designed to rise from and alight on land.

Leading edge — The foremost edge of an airfoil or propeller blade. Also called 'entering edge.'

Left side (engine) — That side which, to an observer looking from the anti-propeller end toward the propeller end, lies on the left-hand side.

Lift — That component of the total air force on an aircraft or airfoil which is perpendicular to the relative wind and in the plane of symmetry. It must be specified whether this applies to a complete aircraft or to parts thereof. In the case of an airship, this is often called 'dynamic lift.' Its symbol is L.

Lift (of a gas) — The difference of density of air and the gas. Both supposed to be under the same conditions of pressure, temperature, etc.

Lift, useful (airship) — The lift available for carrying fuel, and oil, passengers, cargo, food, and drinking water, guns, ammunition, and bombs. Usually determined by deducting from the gross lift all fixed weights; certain allowances of ballast, fuel, and oil; water; spares and tools; crew and equipment. No standard has as yet been established.

Load —

Full — Weight empty plus useful load. Also called 'gross weight.'

Pay — That part of the useful load from which revenue is derived, namely, passengers and freight.

Useful — The crew and passengers, oil, and fuel, ballast other than emergency, ordnance, and portable equipment.

Loading, wing — The gross weight of an airplane, fully loaded, divided by the aera of the supporting surface. The aera used in computing the wing loading should include ailerons, but not the stabilizer and elevators.

Longeron — A fore-and-aft member of the framing of an airplane fuselage or nacelle, usually continuous across a number of points of support.

Mast, mooring — A mast or tower at the top of which there is mounted a fitting, so that the bow of an airship may be secured. It is usually provided with a ladder or staircase and a platform at the top, so that crew and passengers may enter or leave the airship, and also with piping for the supply of fuel, gas and water. Sometimes called 'mooring tower.'

Monoplane — An airplane which has but one main supporting surface, sometimes divided into two parts by the fuselage.

Multiplane — An airplane with two or more main supporting surfaces placed one above another.

Nacelle — An enclosed shelter for passengers or for a power plant. A nacelle is usually shorter than a fuselage, and does not carry the tail unit.

Ornithopter — A form of aircraft heavier than air, deriving its chief support and propelling force from flapping wings.

Overhang — Used in two senses: (1) One half of the difference in span of any two main supporting surfaces of an airplane. The overhang is positive when the upper of the two main supporting surfaces has the larger span. (2) The distance from the outer strut attachment to the tip of the wings.

Pancake, to — To level off an airplane at a greater altitude than normal in a landing, thus causing it to stall and to descend on a steeply inclined path with the wings at a very large angle of attack and without appreciable bank.

Parasite resistance — *See* **Drag.**

Pilot — An operator of aircraft. This term is applied regardless of the sex of the operator.

Pitch of a propeller —

Effective — The distance which an aircraft advances along its flight path for one revolution of the propeller. Its symbol is p.

Geometrical — The distance which an element of a propeller would advance in one revolution, if it were moving along a helix of slope equal to its blade angle.

Mean geometrical — The mean of the geometrical pitches of the several elements. Its symbol is p_g.

Standard — The geometrical pitch taken at two thirds of the radius. Also called 'nominal pitch.' Its symbol is p_s.

Zero thrust — The distance which a propeller would have to advance in one revolution in order that there might be no thrust. Also called 'experimental mean pitch.' Its symbol is p_v.

Zero torque — The distance which a propeller would have to advance in one revolution in order that the torque might be zero. Its symbol is p_a.

Pitch ratio — The ratio of the pitch (geometrical, unless otherwise stated) to the diameter p/D.

Pitot tube — A cylindrical tube with an open end which is pointed upstream (that is, so that the air meets the instrument head-on or is met head-on by the instrument). When the aircraft is flying less than about 200 miles per hour, the instrument measures the impact pressure. When used on aircraft, it is usually associated either with a closed coaxial tube surrounding it or with a closed tube placed near it and parallel to it, the combination being termed a Pitot-static tube. The associated tube has perforations in its side so that it is subjected to static pressure, as distinct from impact pressure. The speed of the fluid can be determined from the difference between the impact pressure and the static pressure as read by a suitable gauge. In common terminology the Pitot-static combination, as above, is often termed simply a 'Pitot tube' or 'Pitot.'

Plywood — A product formed by gluing together two or more layers of veneer. The alternate plies are usually placed with grain at right angles to the adjacent plies.

Propeller —

Adjustable pitch — A propeller whose blades are so attached to the hub that they may be set to any desired pitch when the propeller is stationary.

Controllable pitch, or *variable pitch* — A propeller whose blades are so mounted that they may be turned about their axis to any desired pitch while the propeller is in rotation.

Propeller-blade area — The area of the blade face, exclusive of the boss and the root, that is, of a portion which is usually taken as extending 0.2 of the maximum radius from the axis of the shaft.

Propeller-camber-ratio — The ratio of the maximum thickness of a propeller section to its chord.

Propeller, pusher — A propeller mounted to the rear of the engine or propeller shaft. (It is usually behind the wing cell or nacelle.)

Propeller root — That part of the propeller blade near the boss.

Propeller, tractor — A propeller mounted on the forward end of the engine or propeller shaft. (It is usually forward of the fuselage or wing nacelle.)

Right-side (engine) — That side which, to an observer looking from the anti-propeller end toward the propeller end, lies on the right-hand side.

Rudder bar — The foot bar by means of which the control cables leading to the rudder are operated.

Seaplane — Any airplane designed to rise from and alight on the water. This general term applies to both boat and float types, though the boat type is usually designated as a 'flying boat.'

Shock absorber — A device incorporated in the landing-gear of an aircraft to reduce the shock imposed on the structure when alighting or taking off.

Shock-absorbing devices are usually interposed between the main structure and the wheels, floats, skis, or tail skids, to secure resiliency in landing and taxying.

Stagger — The amount of advance of the leading edge of an upper wing of a biplane, triplane, or multiplane over that of a lower, expressed either as a percentage of gap or in degrees of the angle whose tangent is the percentage just referred to. It is considered positive when the upper wing is forward and is measured from the leading edge of the upper wing along its chord to the point of intersection of this chord with a line drawn perpendicular to the chord of the upper wing at the leading edge of the lower wing, all lines being drawn in a plane parallel to the plane of symmetry.

Stall — The condition of an airplane when from any cause it has lost the air speed necessary for support or control.

Stream-line — The path of a small portion of a fluid relative to a solid body with respect to which the fluid is moving. The term is commonly used only of such flows as are not eddying, but the distinction should be made clear by the contest.

Strut — A compression member of a truss frame. For instance, the vertical members of the wing truss of a biplane (interplane struts) and the short vertical and horizontal members separating the longerons in the fuselage.

Tail group (or **tail unit**) — The stabilizing and control surfaces at the rear end of an aircraft, including stabilizer, fin, rudder, and elevator. (Also called 'empennage.')

Tail-heavy — In a heavier-than-air craft, the condition in which in normal flight, the tail sinks if the longitudinal control is release, that is, the condition in which the pilot has to exert a push on the control stick to keep the given attitude.

Tail slide — The backward and downward motion, tail first, which certain airplanes may be made to take momentarily after having been brought into a stalling position by a steep climb.

Taxi — To run an airplane over the ground, or a seaplane on the surface of water under its own power.

Trailing edge — The rearmost edge of an airfoil or propeller blade.

Triplane — An airplane with three main supporting surfaces, placed one above another.

Veneer — Thin sheets of wood, either sliced with a knife or sawed.

Warp — To change the form of a wing by twisting it. Warping is sometimes used to maintain the lateral equilibrium of an airplane.

Wash — The disturbance in the air produced by the passage of an airfoil. Also called the 'wake' in the general case for any solid body.

Washin — Permanent warping of the wing which results in an increase in the angle of attack near the tip.

Washout — Permanent warping of a wing which results in a decrease in the angle of attack near the tip.

Wind tunnel — An elongated chamber, usually a tube divergent at the ends, through which a steady air stream may be drawn or forced. Models of airfoils, of aircraft, or of propellers may be placed in the middle portion of the tunnel, called the experiment chamber or working section, and supported by suitable balances placed outside the air stream, so that the forces, moments, etc., due to the moving air may be measured.

Wing — A general term applied to a whole or a portion of the main supporting surfaces of an airplane, but in the latter case is usually qualified as right wing, left wing, upper wing, or lower wing, etc.

Wing-heavy — The condition of an airplane in which (in normal flight) there is a tendency for the right (or left) wing to drop, if the lateral control is released, that is, the condition in which the pilot has to exert a lateral force on the control stick to keep the lateral axis horizontal.

Wing rib — A fore-and-aft member of the wing structure of an airplane, used to give the wing section its form and to transmit the load from the fabric to the spars.

Rib compression — A heavy rib designed to have the function of a wing rib and also to act as a strut opposing the pull of the wires in the internal drag-truss. (Also called 'Drag strut.')

Zoom — To climb for a short time at an angle greater than that which can be maintained in steady flight, the airplane being carried upward at the expense of its kinetic energy. This term is sometimes used as a noun, to denote any sudden increase in the upward slope of the flight path.

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